October 2000 Vol. 24 No. 10

TECH BRIEFS

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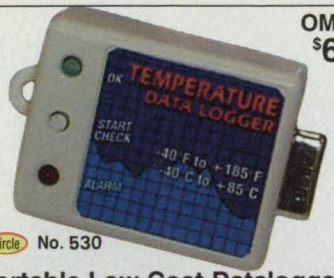

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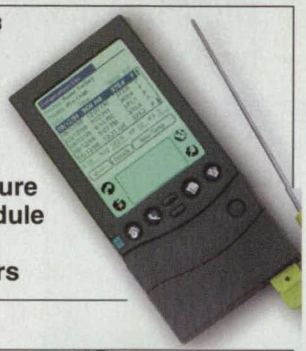

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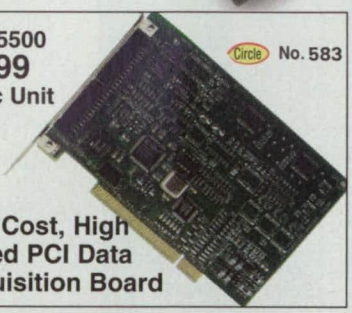

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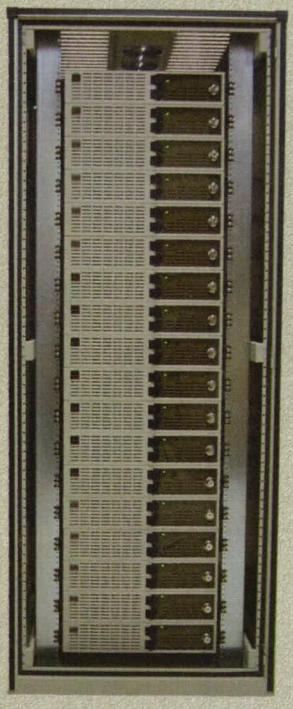

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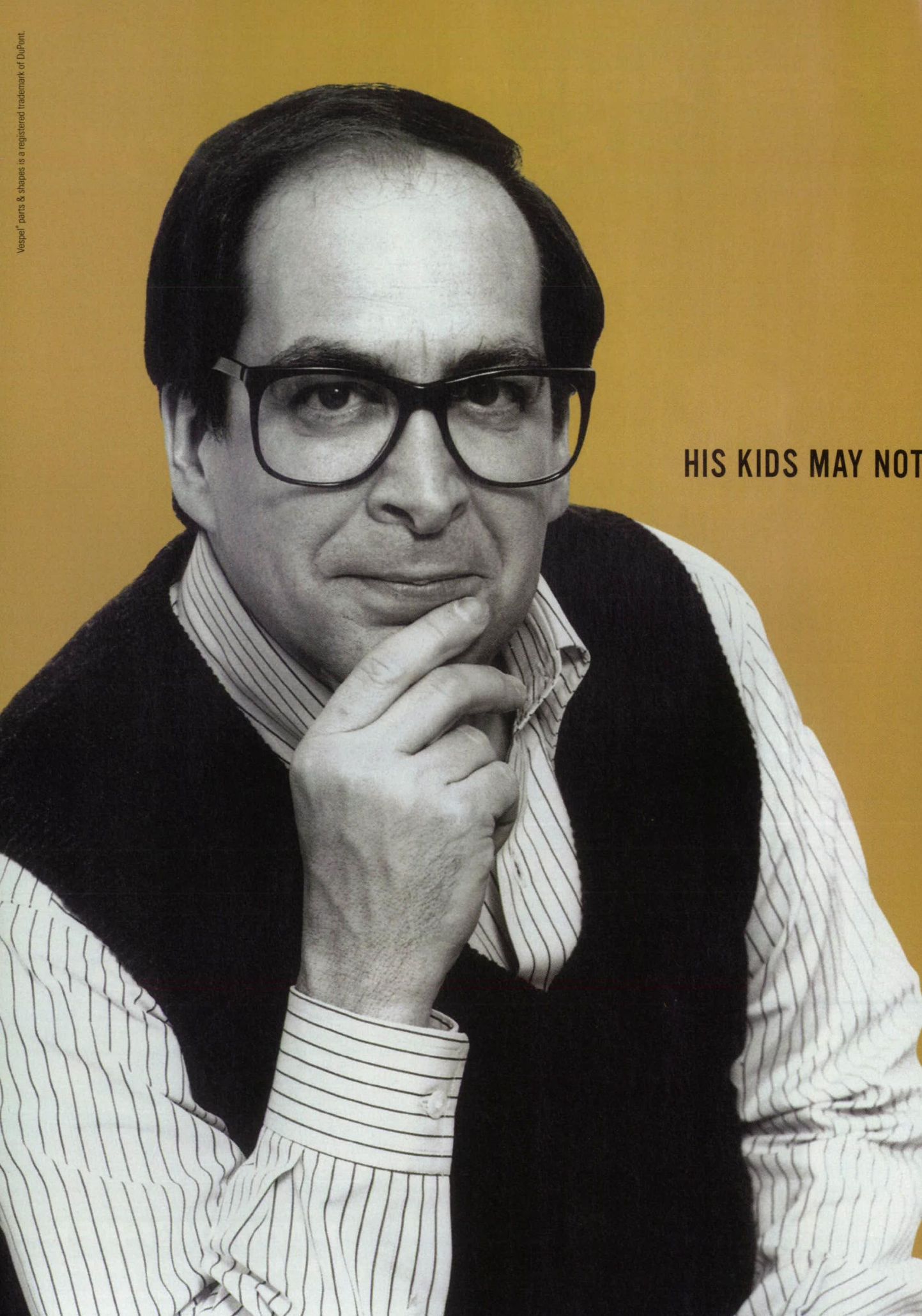

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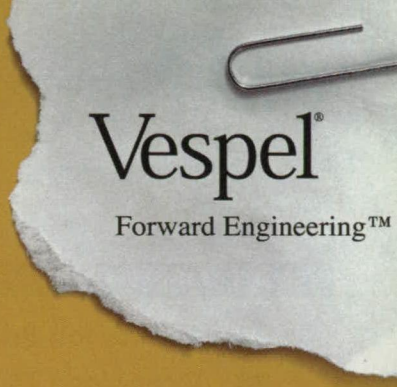

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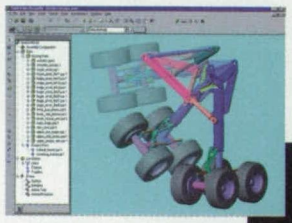

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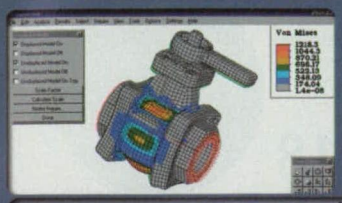
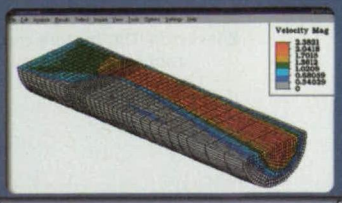
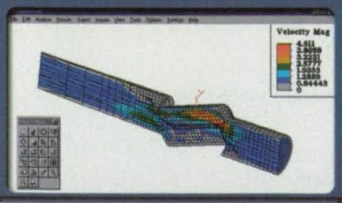
12 Reasons Why Algor Should Be Your FEA Partner



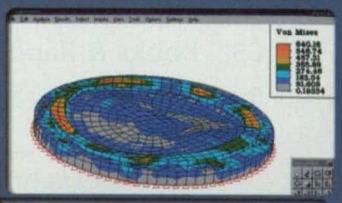
Linear Static Stress - Algor's linear static stress product enables you to capture complex assemblies, such as this valve assembly, from a CAD solid modeler and run a finite element analysis using fast solver technology. Typical loadings are pressure, acceleration, temperature, force and prescribed displacements.



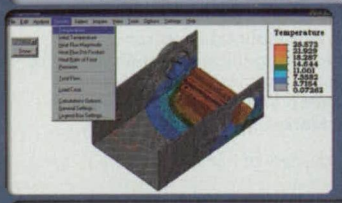
Steady Fluid Flow - Prescribed velocities and pressures provide the loading for this 3-D steady fluid flow analysis of a pipe with a gate valve. Algor's multiple load curves allow for easy data entry for adding loading such as gravity.



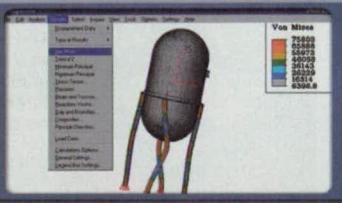
Unsteady Fluid Flow - Unsteady fluid flow of this ball valve system was analyzed using a 3-D CAD solid model. Algor's unique processor solves for velocities and pressures throughout the dynamic event, using a specialized meshing algorithm for high velocity gradients.



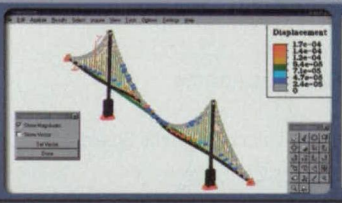
DDAM - Algor's Dynamic Design Analysis Method enables you to analyze the shock response at the mountings of shipboard equipment such as watertight doors, masts, propulsion shafts, rudders, exhaust uptakes and portholes, as shown above.



Transient Heat Transfer - The dynamic effects of a transient heat transfer analysis were needed for the time-dependent temperature loading of this heat sink assembly. Algor's multiple load curves for various loading conditions allow for the simulation of the thermal event.

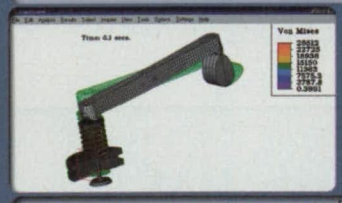


Nonlinear Static Stress - Algor's nonlinear product helps to accurately predict large deformation and large strains caused by static loading. As seen by this water tank, buckling of a structure is one type of failure that can be exposed.

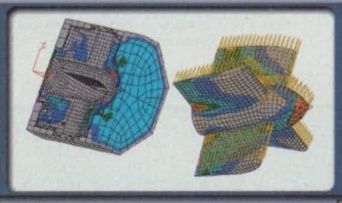


Linear Dynamic Stress- A modal analysis is one of the linear dynamic stress analyses performed on this suspension bridge. Failure can occur when the loading frequency is at the structure's resonant frequency. Algor's linear dynamic analyses accurately predict these frequencies and dynamic effects.

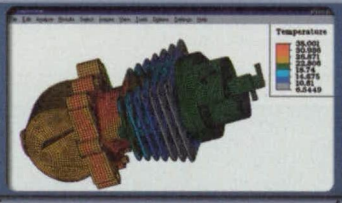
Mechanical Event Simulation (MES) with Nonlinear Material Models - Algor's MES extends full dynamic analysis capabilities to large strain/deformation analyses of nonlinear materials, as shown by this landing gear assembly. Kinematic elements can be used for quicker processing.



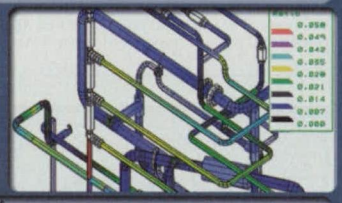
Mechanical Event Simulation (MES) with Linear Material Models - Algor's MES with linear material models allows you to represent a dynamic analysis while solving for kinematics, deflections and stresses of the structure. Analyses using large CAD assemblies, such as this rocker arm assembly model, can be expedited by using kinematic elements.



Multiphysics - Algor's multiphysics products enable you to combine multiple analysis types into one event. Resultant forces from flow around this turbine were calculated and then projected onto the object for a structural analysis. Other multiphysics capabilities include combining heat transfer with fluid flow, heat transfer with static/transient stress and heat transfer with fluid flow and stress.



Steady-State Heat Transfer - Algor's steady-state thermal processor helps predict temperature distribution due to thermal loading. Loading such as convection, radiation, conduction, applied temperatures and surface heat fluxes can be added to an analysis for fast, accurate results. In the case of this engine casing, both conduction and convection were part of the analysis of this 3-D solid model.



Piping Design and Analysis - Algor's piping design and analysis product enables you to calculate the deflections and stresses of this plant piping system and then compare the results with ASME/ANSI code allowables. Loadings can include: dead weight, thermal differences, pressure, wind loads, earthquake loads, time history of forces/displacements, response spectrum, natural frequencies and pitch and roll.

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PRODUCT OF THE MONTH

The IESP and IESF Series of miniature pressure sensors from CUI Stack, Beaverton, OR, feature conductive rubber that senses pressure changes.

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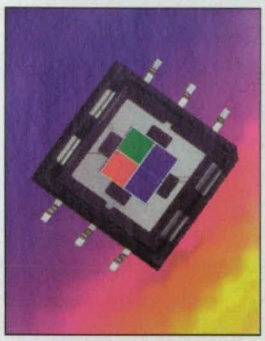
ON THE COVER



The S7505 three-color sensor from Hamamatsu Corp. of Bridgewater, NJ, provides distinct color separation for all three colors: red, green, and blue. The surface-mountable sensor is used as a color-recognition and analysis device in measurement instruments. For more information on the S7505, see the New on the Market section on page 75.

(Image courtesy of Hamamatsu Corp.)

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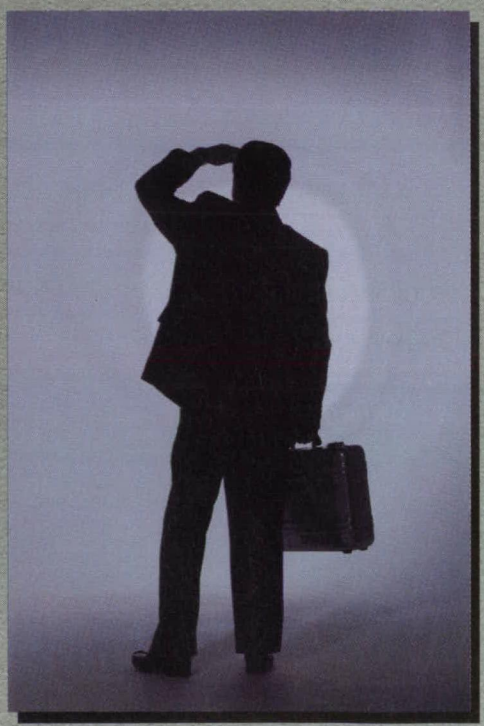

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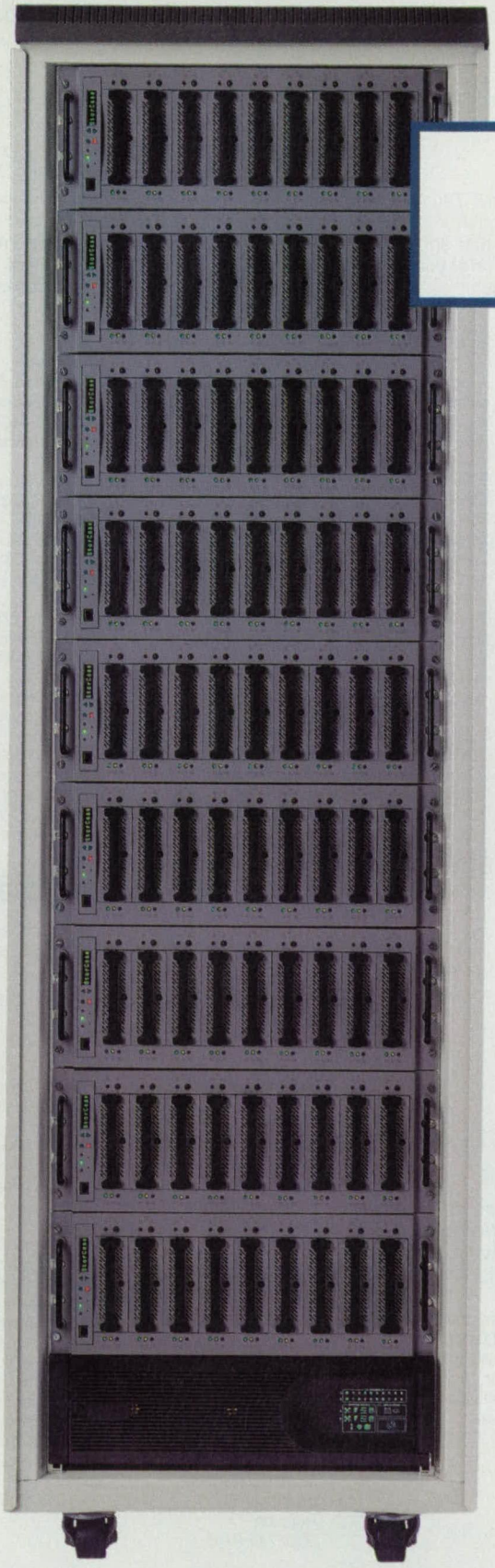

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NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (609) 667-7737 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Carolina Blake
(650) 604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Jenny Baer-Riedhart
(661) 276-3689
jenny.baer-riedhart@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(281) 483-0474
henry.l.davis1@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
Jim Aliberti
(321) 867-6224
Jim.Aliberti-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Sam Morello
(757) 864-6005
s.a.morello@larc.nasa.gov

John H. Glenn Research Center at Lewis Field
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@grc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(256) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
kirk.sharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(352) 294-7822

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(412) 383-2500

Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(440) 734-0094

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
Office of Commercial Technology (Code RW)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mankins
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Terry Hertz
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Glen Mucklow
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Roger Crouch
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rcrouch@hq.nasa.gov

Granville Paules
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(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

B. Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

Julie Holland
NASA Commercialization Center
Pomona, CA
(909) 869-4477

Bridgette Smalley
UH-NASA Technology Commercialization Incubator
Houston, TX
(713) 743-9155

John Fini
Goddard Space Flight Center Incubator
Baltimore, MD
(410) 327-9150 x1034

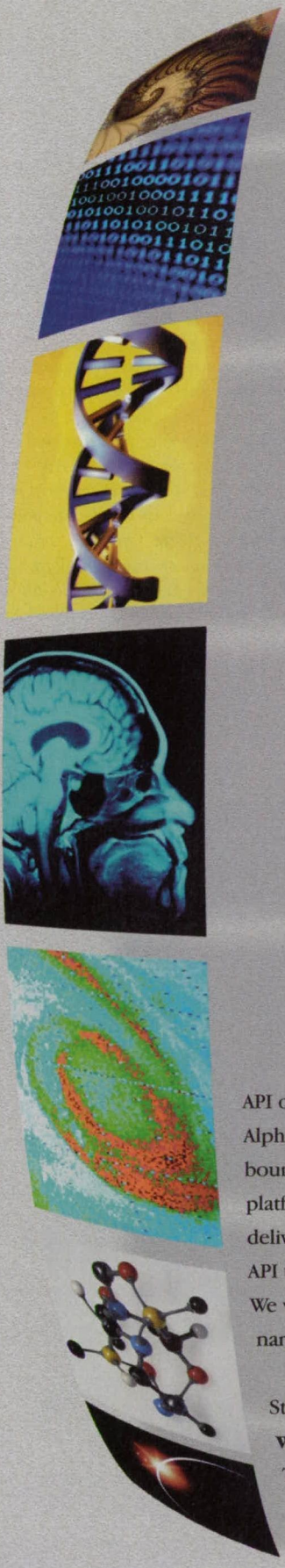
Thomas G. Rainey
NASA KSC Business Incubation Center
Titusville, FL
(407) 383-5200

Joanne W. Randolph
BizTech
Huntsville, AL
(256) 704-6000

Joe Boeddeker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Marty Kaszubowski
Hampton Roads Technology Incubator (Langley Research Center)
Hampton, VA
(757) 865-2140

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.



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In response to your July Reader Forum's Technologies Wanted, I'd like to comment on improved tires for wheelchairs. Polyurethane is available in many different grades of hardness, and has excellent traction and wearability. The request was for electrically non-conductive tire materials to eliminate static build-up. In fact, I think it should be electrically conductive tires to allow static charge to dissipate.

Also, in your April issue, you featured a tech brief on page 63, "Ultracapacitors Store Energy in a Hybrid Electric Vehicle," from Glenn Research Center. It discusses the advantages of electrochemical batteries over conventional storage batteries for a hybrid electric transit bus. I wonder if the same technology could be suitable for wheelchair battery chargers. If this battery is as good as it sounds, it could be a real breakthrough.

Norton T. Pierce
Consulting Engineer
978-369-2984

This may be an odd request, but our company is looking for a portable device that would register the amount of liquid inside a beer keg. We are in the business of liquor auditing, and the current method of measuring the usage of beer is by weighing tapped kegs. It is a backbreaking job. Any suggestions would be welcomed.

A.A. Palacios Collins
BevincoGoldCoast@aol.com

(***Editor's Note:*** *It's certainly not an odd request, and in fact, Andrea Wright of the Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base, OH, has a suggestion for you. According to Andrea, companies such as Lucent and IBM have been researching terahertz radiation, or T-rays, which permit the nondestructive evaluation of myriad opaque samples. Applications include detecting tooth decay, reading text inside envelopes, counting almonds in packaged candy bars, and identifying raisins in cereal boxes. T-ray technology also can be used for seeing through clothing to detect hidden weapons, inspecting luggage, and detecting subsurface rust. The AFRL has recognized the potential combustion and fuel applications of T-rays, which permit the quantification of trace water in jet fuel, since fuel transmits T-rays while water absorbs them. An Air Force-industry partnership with Picometrix of Ann Arbor, MI, resulted in the development of a commercial terahertz radiation system. For more information on the technology, contact Dr. J.R. Gord, AFRL's Propulsion Directorate's Combustion & High Speed Systems Branch, at 937-255-7431.)*

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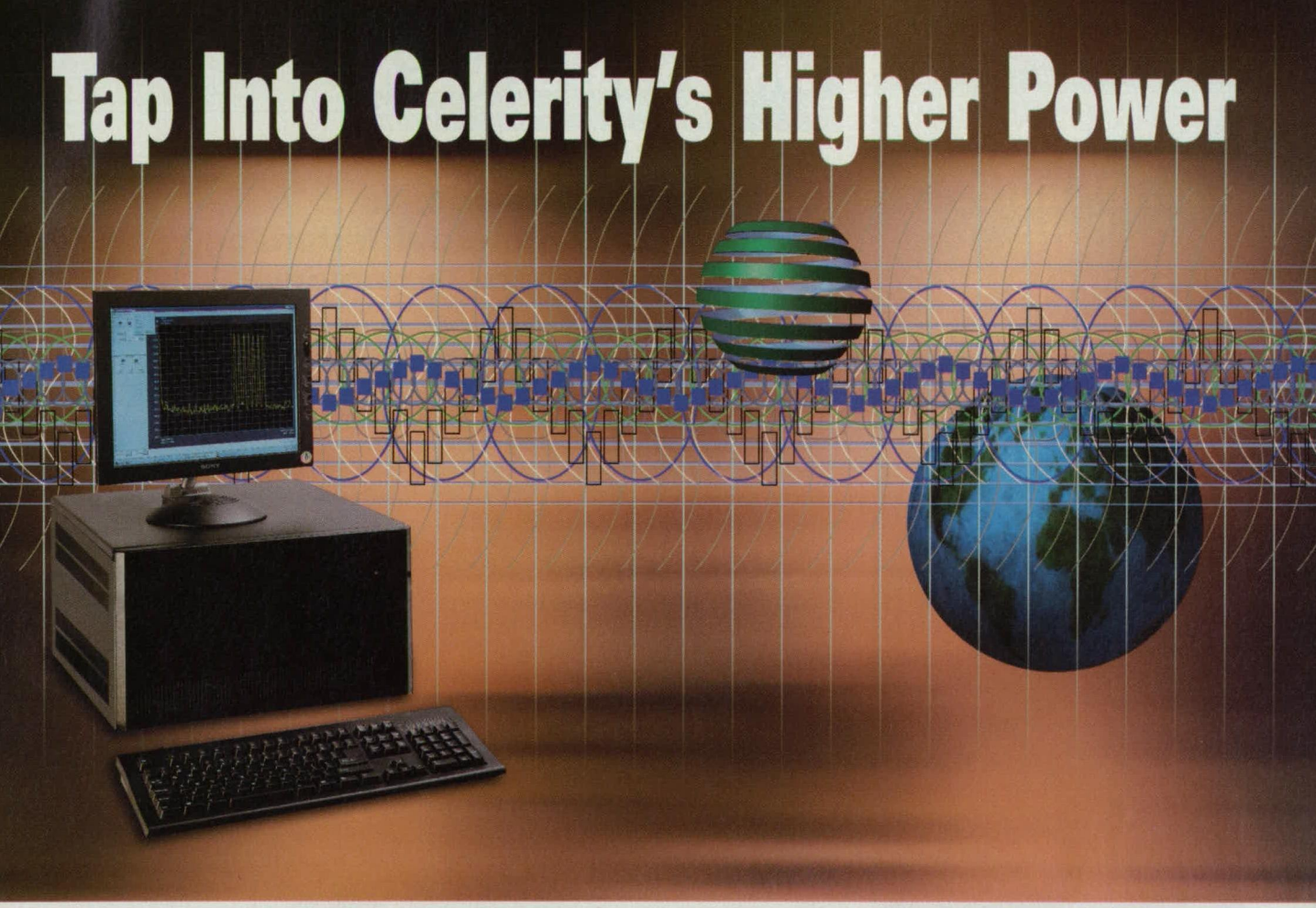

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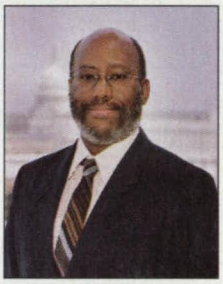
For More Information Circle No. 538

Dr. Robert L. Norwood, Director for Commercial Technology, Office of Aerospace Technology



Dr. Robert L. Norwood is responsible for the overall strategy and management of NASA's Commercial Technology program and the strategic leadership of the NASA Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) programs.

***NASA Tech Briefs:* What are the goals of NASA's Commercial Technology program?**

Robert Norwood: Our goals are to fully utilize NASA's technological resources to strengthen the US economy and improve the quality of life through the creation of commercial technology partnerships with US industry.

NTB: How is the program important to NASA's future?

Norwood: One of NASA's missions is to research, develop, and transfer advanced aeronautics, space, and related technologies to US industry. Technology commercialization will continue to serve as an avenue for applying the benefits of NASA technology to the public good.

NTB: How much of NASA's research and development is performed under contract with private industry?

Norwood: NASA contracts out about 80 percent of its R&D to the private sector.

NTB: If a company is interested in forming a partnership with NASA, what is the best way to proceed?

Norwood: Any firm interested in forming a partnership with NASA should, as much as is practical, define partnership objectives, delineate the resources to be provided by each party to achieve a successful partnership, identify key and committed personnel, and provide a realistic schedule for achieving a successful outcome. With this information, timely and effective partnerships can be accomplished.

NTB: What is the relationship between NASA's Commercial Technology program and the Agency's SBIR/STTR programs?

Norwood: NASA's SBIR/STTR programs are managed within the Commercial Technology program. The primary focus of SBIR/STTR is to develop innovative technologies for enhancing NASA missions, with a strong secondary purpose to assist small businesses in commercializing that technology.

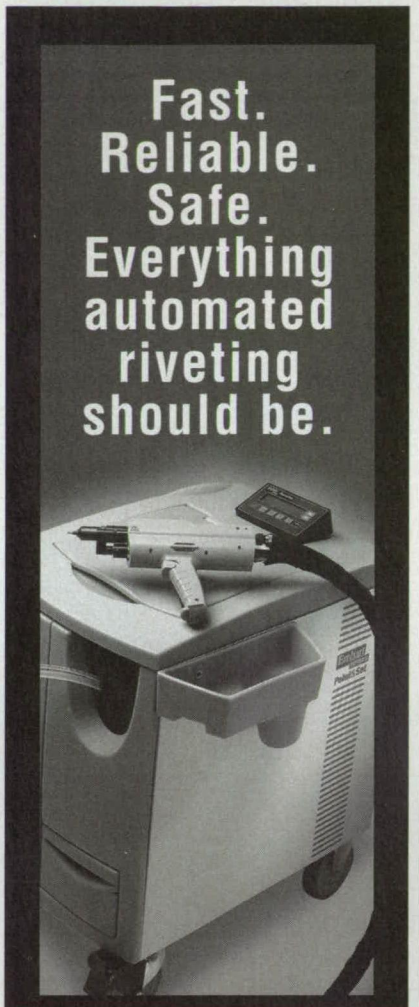
NTB: What have been some of the most important developments to emerge from the Commercial Technology program?

Norwood: There have been many commercial successes over the years — well over a thousand of them have been documented in *Spinoff* magazine alone. I would say that some of the most important NASA contributions have been in the medical field, where we continue to make significant contributions. Many of them are described on our web site at www.nctn.hq.nasa.gov.

NTB: What have you found most rewarding in your work with the program?

Norwood: The most rewarding part of my work is to learn of a new product or service that is successful in part because of the use of NASA technology, or the knowledge that someone's life has been made better or easier through the use of NASA technology.

A full transcript of this interview appears online at www.nasatech.com. Dr. Norwood can be reached at rnorwood@mail.hq.nasa.gov.



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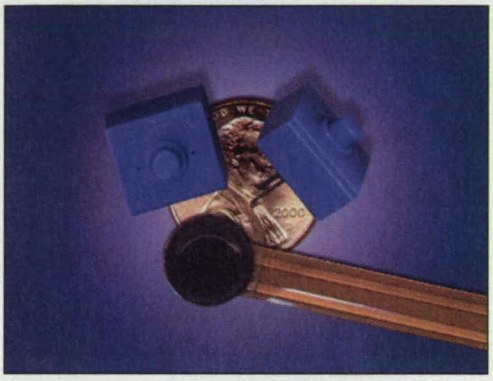


CUI Stack, Beaverton, OR, has introduced the Resin Molded Cover (IESP Series) and the Flexible Board (IESF Series) miniature pressure sensors that use a proprietary material called Inastomer. The material provides both elasticity and conductivity, allowing the sensors to continuously react to the degree of pressure applied. The IESP model features fixed pin mounting terminals, and allows up to 5mA current to be applied. It can be used for contact pressure applications such as water volume, and for pressure, load, and contact of mechanical equipment. The IESF sensor is fastened with a pressure-sensitive tape and can mount to curved surfaces. Applications include clearance sensitivity, object contact, roll pressure, or fingertip contact pressure.

For More Information Circle No. 748

What's New Online

Ever wonder what happens to those innovative NASA technologies described in the pages of *NASA Tech Briefs*? Now you can find out. When you visit the NTB web site at **www.nasatech.com**, you can access the online version of *Spinoff*, an annual NASA publication that describes how NASA-generated technologies have been successfully transferred to commercial products.

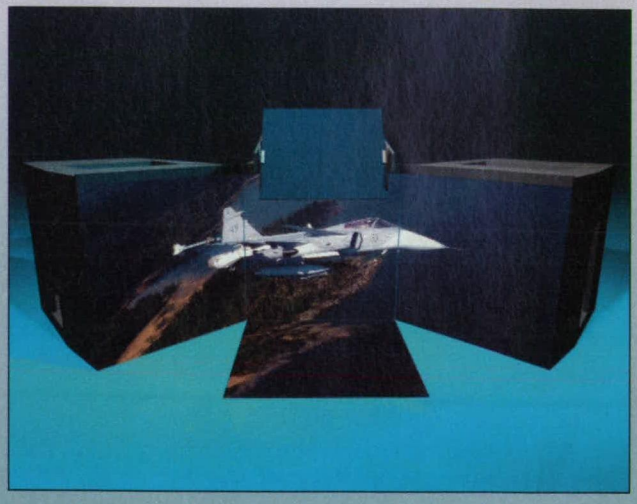
Simply click on *Spinoff Magazine* under the "Connect" heading on the home page, and you'll have access to HTML or downloadable PDF versions of dozens of articles highlighting how industry has taken NASA innovations and "spun-off" high-tech products.

NASA Immersed in New Environment

NASA's Intelligent Synthesis Environment (ISE) Initiative aims to enable geographically dispersed teams of engineers to collaborate in full sensory environments. As part of the initiative, NASA's Glenn Research Center in Cleveland, OH, installed a RAVE™ (Reconfigurable Advanced Visualization Environment) system from Fakespace Systems (Novi, MI), which will be used as part of a multi-facility network of collaborative immersive environments.

The RAVE system at NASA Glenn consists of three self-contained modules that can be used as independent stereoscopic projection display systems, or in a variety of groupings. Each module features an 8-foot wide by 7.5-foot high rigid, rear-projected screen at one end of an 11-foot deep structure containing one or more high-resolution CRT projectors. The system provides stereoscopic visualizations that appear to have a real dimensional presence when viewed with special shutter glasses. Equipped with air casters, the modules can be raised 1" off the ground so that they can be rolled into different viewing configurations. An overhead projector/mirror addition to one module produces images on the floor to enable a four-sided immersive room.

At NASA Glenn, the system will be used to explore computational fluid dynamics and structural analysis simulations. As part of ISE, engineers at other NASA sites will utilize broad bandwidth links between systems to share the immersive environment with Glenn. The real-time, remote collaboration will allow the engineers to work together as if they were at the same location. Other facilities using compatible systems are Langley Research Center (Hampton, VA) and Marshall Space Flight Center (Huntsville, AL).



Visit the ISE web site at http://ise.larc.nasa.gov. For more information on RAVE, visit www.fakespacesystems.com.

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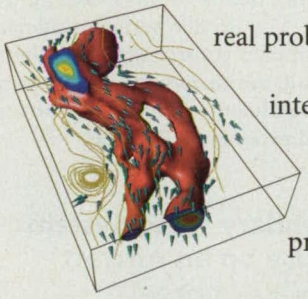

MATLAB includes powerful visualization features for creating images like this isosurface of wind speeds over North America.

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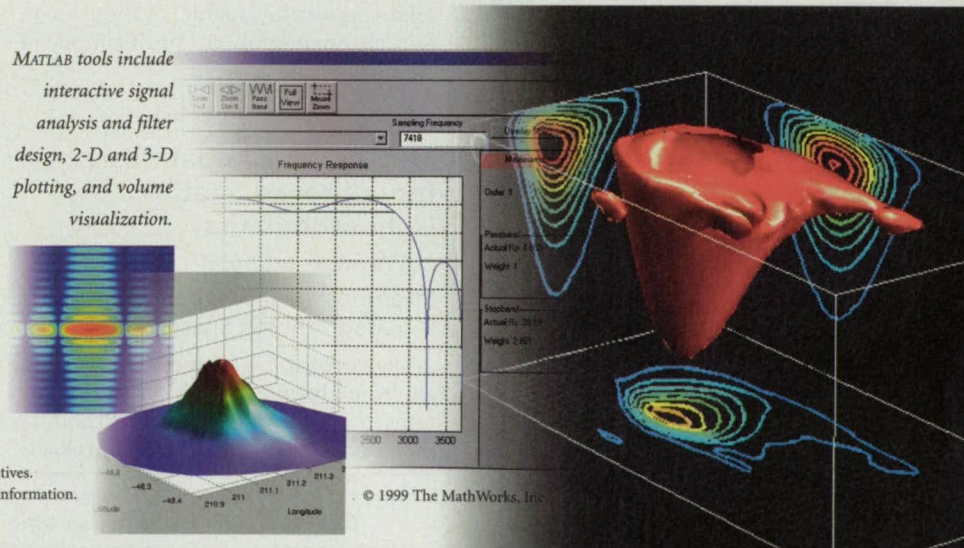

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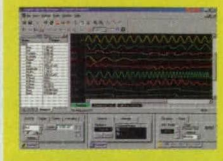

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NASA Patents

Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:

Porous Article with Surface Functionality and Method for Preparing Same

(U.S. Patent No. 6,022,902)

Inventor: Steven L. Koontz, Johnson Space Center

Solid phase supports are currently used commercially for separation or solid phase synthesis. In general, the efficiency of solid phase synthesis and separation processes depends on the surface area of the solid phase material. Porous materials offer the advantage of higher surface area per unit volume than the corresponding full-density solids, permitting vastly improved synthesis and separation performance per unit volume of solid material. The method of the inventors provides, through remote plasma discharge, a mild way of introducing functionality to a porous article, one that has an exterior surface, a bulk matrix, and pores extending from the exterior surface into the bulk matrix. The pores define an interstitial surface. The bulk matrix is formed, at least in part, of the same organic polymer comprising carbon and hydrogen atoms. The exterior and interstitial surfaces are formed, at least in part, of the same organic polymer comprising carbon and hydrogen atoms, which has been modified so that some of the hydrogen atoms are replaced with functional groups including amino, hydroxyl. carbonyl, and carboxylic acid. The surface-functionalized article may be used, for example, as a solid support in organic synthesis or in the chromatographic purification of organic or biochemicals.

Method and Apparatus for Improved Spatial Light Modulation

(U.S. Patent No. 6,055,086)

Inventors: Colin Soutar and Richard D. Juday, Johnson Space Center

Spatial light modulators (SLMs) operate by modulating a beam in two dimensions by changing the intensity and/or phase of the light wave in a controllable manner. Many optical processing systems utilize liquid crystal video displays as an inexpensive and readily available alternative to SLMs. In the present invention, at least one electrically controlled polarizer unit and an analyzer unit are combined with a pixelated birefringent medium such as a liquid crystal video display. Both the polarizer and the analyzer have a number of available polarization states that can be accessed by an electrical signal. The combination of the polarizer and analyzer units makes it simple and fast to reconfigure the modulation, described by the Jones matrix of the spatial light modulator. A controller performs calculations and supplies control signals to the polarizer unit, the analyzer unit, and the spatial light modulator in order to obtain the optical processing objective.

Secondary Wing System for Use on an Aircraft

(U.S. Patent No. 5,992,796)

Inventor: Brian E. Smith, Ames Research Center

The patent describes a secondary wing system having a single pivoting canard that can be deployed to augment the lift, stability, and control of an aircraft during various flight regimes, and that can be conformally retracted into the fuselage in order to minimize drag at high speeds. The canard has an aerodynamically efficient planform shape that reduces the engine power required for low-speed operation, thus resulting in lower noise levels during takeoff, climbout, approach, and landing. The retractable canard has leading- and trailing-edge control surfaces to enhance the aerodynamic performance of the plane. The system provides a novel assembly of retractable fairings that streamline the leading and trailing edges of the canard when it is stowed, thus optimizing aerodynamic efficiency for high-speed flight. The canard can be deployed and retracted during flight. The deployment mechanism includes a circular mounting ring and drive mechanism that connects the canard with the fuselage and permits it to rotate and to change incidence.

For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 12 for a list of office contacts.

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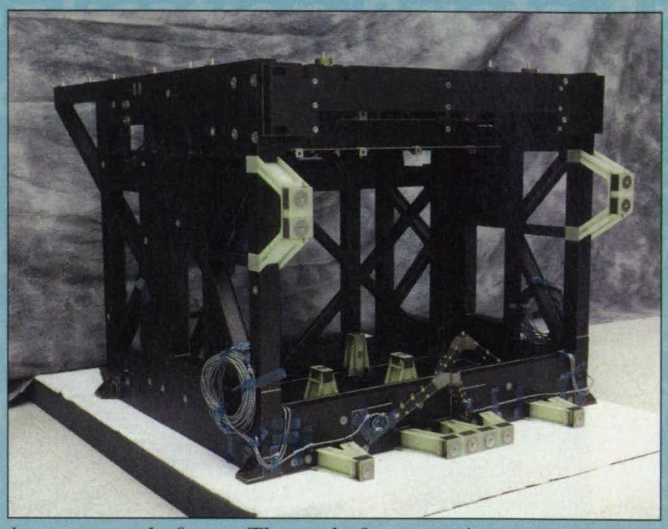

NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, is building the Tropospheric Emission Spectrometer (TES), which is scheduled to launch in June 2003 aboard NASA's Aura Spacecraft. The spacecraft is part of NASA's Earth Science Enterprise, a series of satellite missions that will examine the earth's environment and how it is changing. Composite Optics designed, fabricated, tested, and delivered a structure and optical bench for the TES.

TES is an infrared satellite instrument designed to measure the state of the earth's troposphere — the layer of the earth's environment that extends from the earth's surface to about ten miles in altitude. TES will obtain data on tropospheric ozone and other gas molecules that lead to ozone formation. From the TES data, NASA scientists expect to learn about the interaction of ozone with other chemicals.

The composite technologies used for TES are the latest examples of new generation lightweight and stable space instrument platforms. These platform requirements are especially demanding due to the precise thermal control and dimensional stability necessary for proper operation of the sensitive optical instruments aboard. Thomas Glavich, project manager at JPL, explained that TES "is one of JPL's most complex instrument structures ever attempted, and the testing of it went perfectly. The testing of the structure was a critical program milestone and it exceeded our expectations."

For more information Circle No. 740

CFD Models Improve Space Station Module

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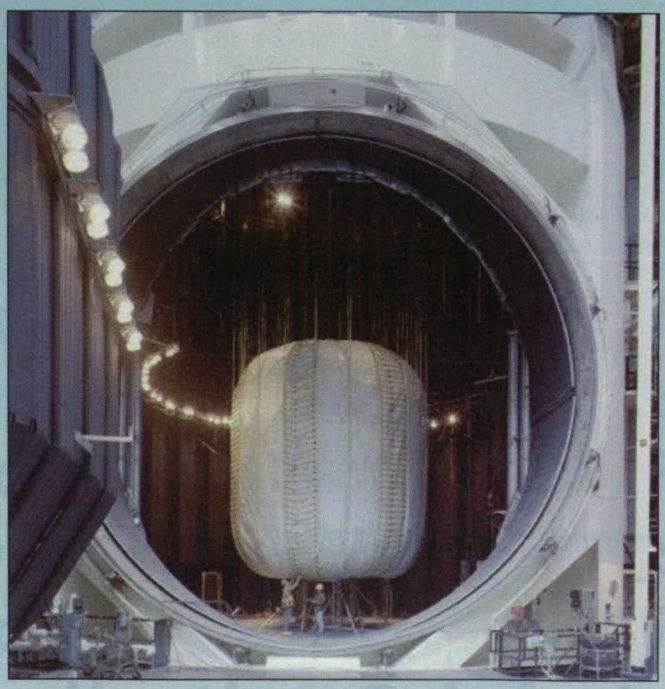

The fully inflated module in JSC's vacuum chamber.

Lockheed Martin engineers have developed a computational fluid dynamics (CFD) model to simulate climate control in the International Space Station (ISS). The model also includes human metabolic inputs as boundary conditions for a CFD model. It was created to evaluate and improve airflow and water vapor concentration in NASA's TransHab Module, the habitation module for the ISS. The inflatable module will provide a home for up to six astronauts.

Concerns were raised about climate control within the module, especially condensation build-up. CFD software was used to model fluid flows within the module. IGES files were exported from Pro/ENGINEER CAD software (from Parametric Technology Corp. of Waltham, MA) into Fluent's GeoMesh CFD preprocessor program. TGrid was used to extrude the geometry into a volumetric mesh.

Based on the results gained from the CFD models, engineers added ten portable fans within the module, and diffusers were added to all vents to re-direct airflow. Human metabolic models, used as mass flow rate boundaries, exhaled carbon dioxide and water vapor. With the new models, NASA was able to improve environmental conditions within TransHab, improving airflow and eliminating condensation. The CFD software also has been used to analyze the X-38 ISS escape module, designed at NASA's Johnson Space Center in Houston.

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For More Information Circle No. 534

Commercialization Opportunities

Tunable Terahertz Source Based on Near-Infrared Diode Lasers

This apparatus could serve as a prototype of tunable far-infrared sources and heterodyne up- and down-converters for fiber-optic communication systems and for testing infrared systems in general.
(See page 40.)

Highly Efficient Thermoelectric Unicouples

Advanced unicouples with carefully tailored combinations of thermoelectric materials are being investigated to develop generators with relatively high conversion efficiencies. Conversion efficiencies as large as 15 percent have been predicted.
(See page 42.)

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(See page 44.)

Personal Cabin Pressure Alarm

Compact instruments as small as personal pagers would warn users when aircraft cabin pressure drops to dangerous levels. Pressure below a certain level triggers a 30-min. timer before the alarm is triggered. Further drop in pressure can trigger the alarm immediately.
(See page 46.)

Glass Cure Plates for Fabricating Flat Composite Panels

Costs and maintenance are lower when glass is used instead of aluminum.
(See page 56.)

Ultrasonic Bubble-Sizing Instrument

An ultrasonic instrument developed for measuring the sizes of bubbles in the human body is expected to aid research in decompression sickness and other conditions associated with gaseous emboli.
(See page 62.)

SiC/SiC Composites With Improved BN Coating on Fibers

A new method of fabricating composites with improved boron nitride fiber/matrix interfacial layers creates a BN coating that helps to deflect cracks away from the fibers.
(See page 69.)

Silica-Filled EPDM Rubbers as Ablative Insulating Materials

Although these materials have been developed for use on solid-fuel rockets, they may also be useful in environments for short-time protection against high heat.
(See page 70.)

Graphite/Conductive-Epoxy Electromagnetic Shielding

Performance results suggest that this composite material can provide thinner and lighter shields than aluminum against EMI and be equally as strong.
(See page 71.)

October 2000

Motion CONTROL Tech Briefs

Photodiodes: a Smart Motion Control Solution ..... IIb

Rolling-Piston Compressor with Flow-Through Lubrication 4b

Closed/Momentary-Opening/Closed Solenoid Valve 6b

Myoelectric Teleoperation for Robotics and Prosthetics 7b

Formulation and Algorithm for Multi-Flexible-Body Dynamics 8b

New Products 10b

Cover: Lee Controls' Profile Rail System—see New Products. Photo courtesy Lee Controls Inc.

PHOTODIODES:
A Smart Motion Control Solution

The automotive industry is increasingly using photodiodes to provide greater levels of automation and product sophistication.

Increased traffic levels add to the pressure on automotive manufacturers to provide smarter cruise controls with collision avoidance features.

Mechanical and piezoelectric motion control has already reached nanometer-level precision and repeatability. While some further improvement in these areas can still be expected, a more commercially significant trend is towards "smart" systems, where feedback signals control motion using microprocessors and DSP-based controllers. The feedback signal is often derived from some type of optical sensor, frequently utilizing a photodiode. This article briefly reviews the technology and advantages of photodiodes, and then examines some emerging applications in the automotive industry, which is one of the fastest-growing markets for smart motion control systems.

A photodiode is a special type of semiconductor diode that converts incident light into a useful electronic signal. The majority of photodiodes are silicon-based and respond to light in the 350- to 1000-nm range, i.e., the near-UV through near-IR. Like other solid-state components, photodiodes are small, simple, rugged, and reliable. Moreover, advances in wafer fabrication technology means they can be manufactured in high volume for relatively low unit costs. Obviously, all these advantages are direct benefits in a motion control system.

Just as important for OEMs, photodiode functionality and performance are highly customizable. For example, by fabricating small, low-capacitance devices, the response can be as short as 300

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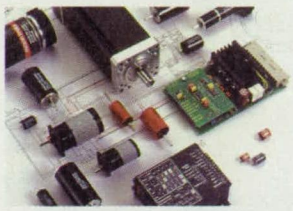
The Maxon product line consists of quality high efficiency DC motors, which are available with gearheads, encoders, tachometers, and controllers. Our products range from cost-effective ferrite magnet motors to current state of the art rare earth magnet motors. Brushless motors also are offered.



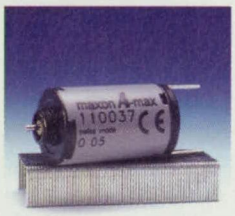
Our patented rhombic wound moving coil motors offer several advantages over conventional DC motors such as much longer brush life and extremely low electrical noise, low mechanical time constant for fast acceleration, low current consumption for extending battery life, no cogging for smooth rotation even at low speeds, and linear speed-torque constants for simple, accurate control.

Typical applications include air samplers, chart recorders, miniature pumps, chopper wheels, laser measuring devices, microscope stages, surgical devices, data storage devices, vision systems, and printers/labelers.

For more information, call or fax Mr. James Talent, Maxon Precision Motors, Inc., Burlingame, CA. Tel: 800-865-7540, Fax: 650-697-2887.

Circle No. 602

12 mm REDUCED COST MOVING COIL MOTOR



Maxon's new A-max 12 mm (0.47 in) diameter motor delivers the performance and lifetime of a moving coil motor, but at a reduced cost due to improved automated manufacturing processes. The patented rhombic moving coil design provides for long life, low electrical noise, fast acceleration and high efficiency. The ironless rotor allows for zero cogging and simple accurate control. The motor is available either with a single shaft or with a passing shaft, and is rated at .5 or .75 watts. Other standard options include ball bearings/sleeve bearings, and terminals/leads. The motor length is 20.6 mm (0.81 in) and weighs in at 10 to 12 g (.35 to .42 oz) depending on configuration. Several different windings are available to match desired speed with available voltage. Ambient temperature range is from -30° to 85° C (-22° to 185° F), while the maximum efficiency is up to 71% depending on the winding. The maximum continuous torque from the motor alone is up to .99 mNm (.14 oz-in). Matching gearheads are also available with ratios ranging from 4:1 to 1,118:1 capable of delivering up to 530 mNm (75 oz-in) of intermittent torque. Matching encoders are also available.

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500 WATT BRUSHLESS MOTOR

Maxon's new "EC" series of brushless motors are electronically commutated, thus enabling extremely long motor life, since there are simply no mechanical brushes to wear out. Hall effect sensors are built in to the motor in order to provide feedback to the control electronics. By assembling the motor such that the coils are outside the rotor, good heat dissipation and high overload capability are attained. Diameter is 60 mm (2.4 in) while the length is 173 mm (6.8 in). Continuous output power is 500 watts, while maximum speed is 7,000 RPM. Ambient temperature range is -20° to 125° C (-4° to 257° F). Utilizing high-energy neodymium magnets results in a very responsive mechanical time constant of 4 ms, while minimizing overall size. Using electronic commutation allows for minimum electrical noise; in fact these motors are CE approved, signifying electromagnetic compatibility in the European market. Motors are offered with both "Y" or "delta" configurations to optimize performance. Complementing the motors are gearheads with ratios from 3.7:1 to 307.5:1 capable of 180 Nm (132 ft-lb) of intermittent torque. Also offered are encoders, resolvers and brakes.

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ps. On the other hand, other devices can offer over 10 decades of linear response. Also, photodiodes can be fabricated as single elements or multielement arrays, as well as position-sensing detectors, where a duplex electrical signal indicates the x-y centroid position of an incoming light beam.

Photodiode manufacturers have also supported the development of sophisticated "smart" applications by offering custom assemblies that incorporate optics and/or amplifier and signal-processing electronics. Indeed, many OEM customers have found it more cost-effective to incorporate a photodetector subassembly, in which the individual components are all preassembled, aligned, and fully tested. Modern packaging techniques, such as plastic encapsulation and surface-mount interconnects, enable this integration to be provided in an economical manner.

Two recent advances, the large-area avalanche photodiode (LAAPD) and the Filtrode®, both patented by Advanced Photonix, offer specialized performance benefits for motion control applications. The LAAPD uses internal amplification to generate multiple charge carriers from a single incoming photon, yielding high sensitivity and low-light performance characteristics formerly only found in bulky, fragile vacuum-tube-based detectors. The Filtrode® is a photodiode in which a thin-film optical coating is deposited directly onto the detector's surface, enabling it to reject or accept specific wavelengths (Figure 1).

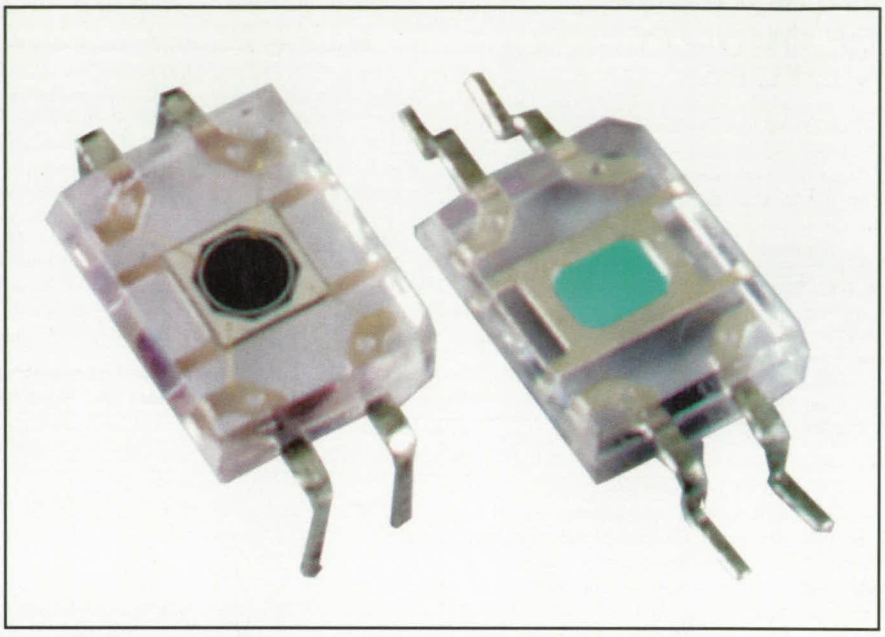

Figure 1. The Filtrode is a photodiode that has a wavelength-sensitive filter directly on its input surface.

Automotive Applications

Automotive applications place unique demands on photonic devices. Simple economics dictates that these components must provide high reliability, meaning years of service, at a low cost. But at the same time they must withstand constant vibration over a range of frequencies. Also, devices outside the passenger compartment must endure extreme changes in temperature and humidity, as well as exposure to grit, oil, and dirt. Obviously this necessitates excellent bonding and packaging techniques. In fact, to supply devices to the automotive market, component manufacturers must meet a very strict set of qualifications referred to as QS 9000. These are similar in philosophy to the widely used ISO 9000, but even more stringent.

An interesting smart motion control

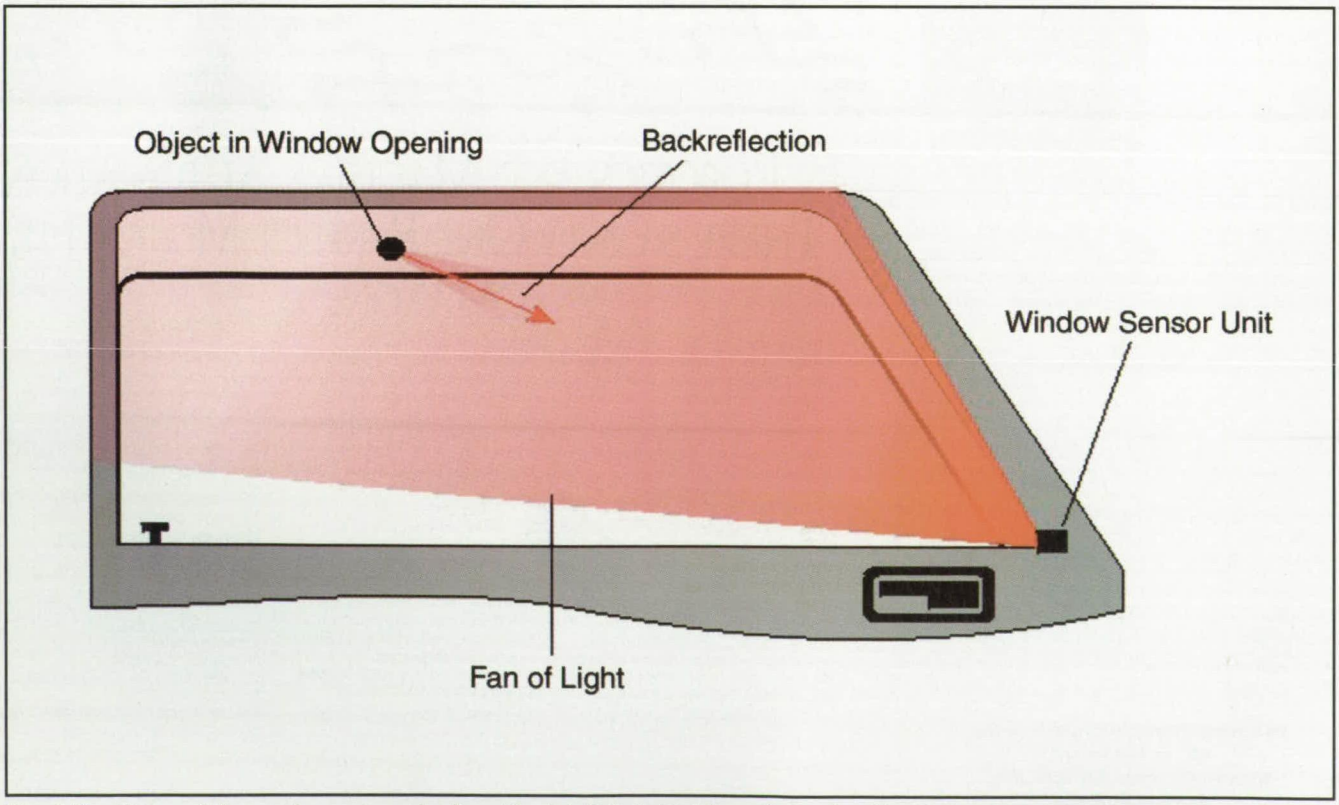

Figure 2. "Smart" power windows may incorporate wavelength-sensitive photodiodes to detect changes in the reflected intensity from an LED light source.

problem in the automotive industry involves power windows. At present, power windows offer automatic travel only in the opening direction: this feature allows a window to be fully opened without the switch having to be continuously held down. This "hands-free" operation is obviously an advantage at toll booths, drive-through services, etc. Clearly, it would be just as advantageous to have hands-free closing as well. At present, this feature is not offered because of the danger of causing trauma to an object—e.g., a child's finger—accidentally placed in the window's opening; the switch must therefore be actively held down throughout the entire range of travel.

Unfortunately, a simple mechanical interrupt based on resistance pressure is not a viable solution to this problem. In order to force a good wind-rain seal, the closing window is typically accelerated over the last inch or two of travel. Consequently, the reaction time of a resistive-force-based loop would not be fast enough to completely eliminate the potential damage to a small finger. Engineers are therefore developing potential optical solutions.

One approach that has been investigated uses a near-infrared light-emitting diode (LED) located in the corner of the window. A low-cost cylinder lens is used to fan the LED's output to produce a flat sheet of light that is parallel to the window and close to its inner surface (see Figure 2). A photodiode-based sensor is located in the same module, with wide-field optics to gather light from the entire window area. The system is set up so that any sudden change—increase or decrease—in the photodiode signal will momentarily disable the automatic window-closing system.

Eliminating False Positives

A significant limitation of this approach is the number of false positives: the system can be fooled by sudden changes in the ambient light level, such as would occur when passing through the shadow of a building or a large tree. The goal of system designers is to reduce background effects while still delivering one hundred percent response to the industry-standard test: a 4-mm-diameter opaque tube placed in the furthest corner of the window.

A possible solution that is currently being investigated relies on wavelength discrimination. Advanced Photonix's Filtrode technology offers an economical route to this goal. The light source is an LED that emits over a narrow wavelength band, and the Filtrode coating is designed to transmit only this same wavelength band. This approach not only improves discrimination by orders of magnitude, but preserves the key goals of simplicity and low cost.

Fully automated window operation will also allow for smarter climate control. For example, the windows could be programmed to close automatically in response to rain falling on the car. Also, when the temperature of a parked car reaches a certain level, the windows would open and close to regulate the interior temperature. Photodiodes would also be used to determine the temperature by measuring the ambient near-infrared intensity at two different wavelengths.

Photodiodes and Cruise Control

As cars become smarter, photodiode-based systems may also play an increasing role in controlling the motion of the car itself. An early example of this is the smart cruise control, already available on some German luxury models. Here a photodiode is mounted on the front of the car, together with an LED sending unit. The photodiode detects light that is reflected from objects in front of the car, allowing continuous ranging by measuring time or phase delay.

In practice, the cruise control is set at the desired speed. When an object enters the lane in front of the car, the cruise speed is lowered as necessary to maintain a minimum distance. When the vehicle in front accelerates or exits the lane, the original cruise speed is restored. In contrast to the automated window problem, this collision avoidance application utilizes basic high-speed photodiodes, where rugged packaging and low cost are the most important design parameters.

Finally, looking even further into the future, automotive engineers are exploring the concept of "drive by wire" and "drive by fiber." Analogous to the systems used in some airplanes, the controls would no longer be mechanically linked to the wheels and transmission, etc. Photodiodes are expected to play a key role, not only in transmitting information, but also as optical sensors to monitor the steering and transmission functions.

For more information, please contact the author of this article, Brock Koren, president of Advanced Photonix, 1240 Avenida Acaso, Camarillo, CA 93012; (805) 987-0146; fax: (805) 484-9935; e-mail: bkoren@advancedphotonix.com; www.advancedphotonix.com.

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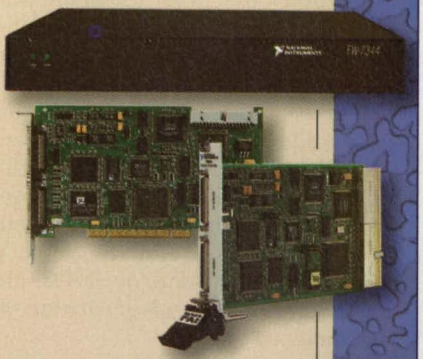

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Rolling-Piston Compressor With Flow-Through Lubrication

Advantages are high efficiency and insensitivity to orientation.

Lyndon B. Johnson Space Center, Houston, Texas

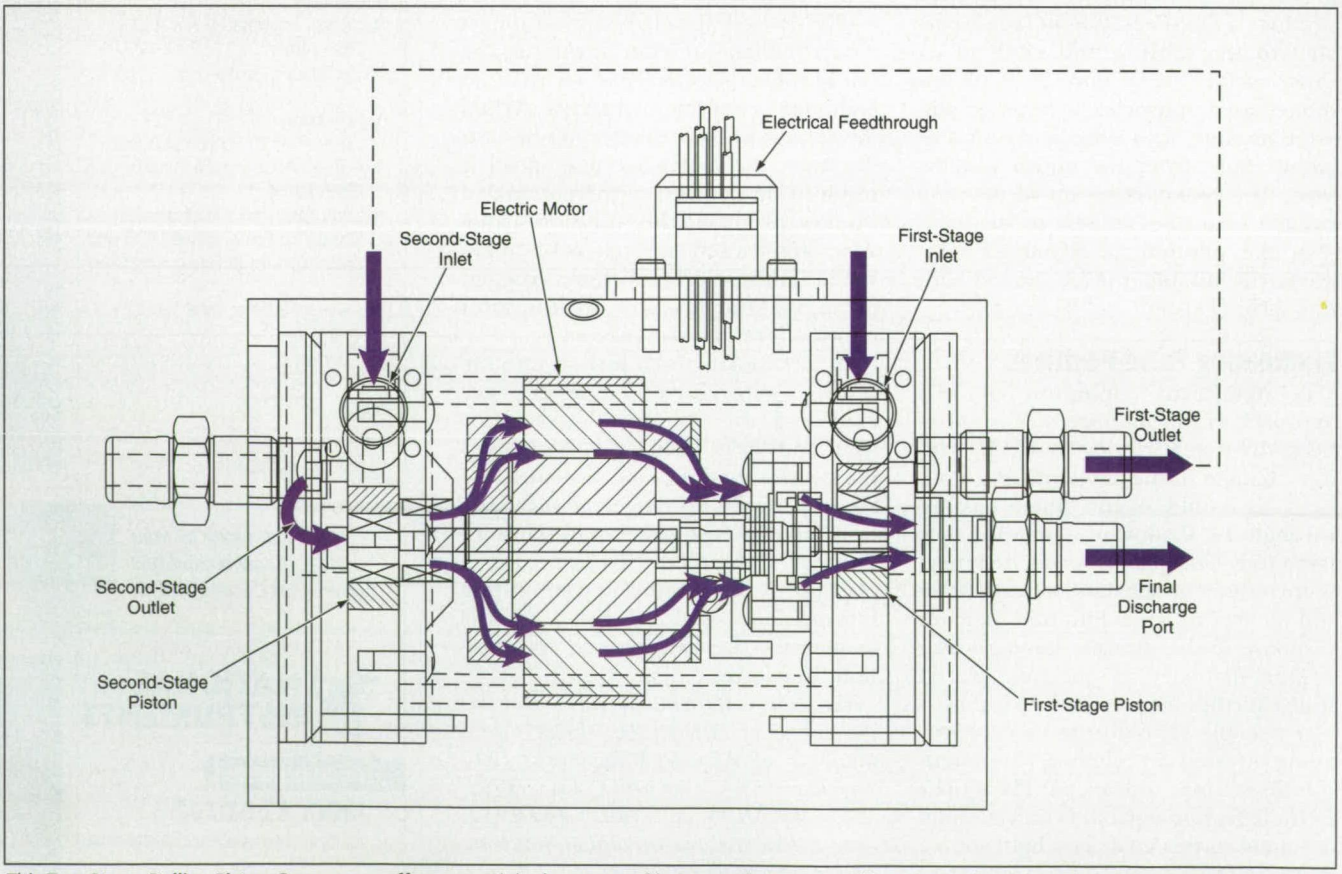
The figure presents a simplified and partly schematic view of a two-stage rolling-piston compressor that is undergoing development for use as the prime mover in a vapor-compression heat pump. In comparison with equally rated compressors used heretofore in vapor-compression heat pumps, this compressor would perform better, would operate with higher efficiency, would be smaller, and would weigh less. Unlike prior compressors, this compressor could function in any orientation with respect to the gravitational field and/or acceleration, or in the absence of gravitation and acceleration.

Like most prior compressors, the present developmental compressor is designed to be part of a hermetic vapor/liquid-flow system wherein a refrigerant fluid and a lubricating oil are allowed to mix and flow together. In a typical prior compressor, a sump in the compressor housing is used to collect and hold most of the oil; this is necessary to prevent fouling of control valves and heat exchangers with excessive amounts of oil. The oil-retention function of the sump depends on the proper orientation of the sump with respect to acceleration and gravitation. In contrast, the present developmental compressor does not contain a sump; instead, as explained below, the compressor operates with flow-through lubrication, and oil is allowed to flow throughout the system. There being no sump and no need to concentrate oil at a single location in the system, the compressor and the rest of the system become insensitive to gravitation and acceleration.

The rolling-piston concept was chosen for development of this compressor for several reasons:

- Rolling pistons can readily be designed to operate at speeds greater than those of reciprocating pistons; this makes it possible to reduce sizes and weights of moving components without reducing throughput.
- The lubrication requirements of rolling-piston compressors appear to be minimal; a rolling-piston compressor can operate satisfactorily, without a sump, when lubricated by a small amount of oil (an oil mist) circulated with refrigerant.
- The requirement for low oil circulation is consistent with the need to minimize the potential for fouling of heat exchangers and control valves with oil.
- Rolling-piston compressors are quite tolerant of the entry of slugs of liquid — refrigerant or oil or both. Thus, in comparison with other compressors, rolling-piston compressors function with less dependence on precise control of liquid inventories.

A typical preliminary design calls for the developmental compressor to circulate the refrigerant fluid between an evaporator at a temperature of 240 K and pressure of about 10 psi (≈69 kPa) and a condenser (radiator) at a temperature of 295 K and pressure of about 100 psi (≈690 kPa) while transferring heat from the evaporator to the condenser at a rate between 300 and 500 to 500 W. The refrigerant fluid would likely be R-134a (tetrafluoroethane). The lubricant would likely be a synthetic polyol-ester oil, the amount of oil being of the order of 10 to 20 mass percent of the refrigerant/lubricant mixture. The motor speed in



This **Two-Stage, Rolling-Piston Compressor** offers potential advantages of better performance and less size and weight, relative to previously developed heat-pump compressors.

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typical operation would be of the order of 10,000 rpm.

Although the design calls for two stages to develop the pressure ratios needed for the required temperature lift of 55 K, both stages can be contained in a single housing, where they can be driven by one motor via one shaft. By suitable diversion of inlet and outlet flows, the two pistons can be operated in series (as two stages) to obtain a higher temperature lift at a smaller flow rate, or the two pistons can be operated in parallel (as a single stage) for a somewhat lower temperature lift at a greater flow rate. Depending on the required evaporator and condenser temperatures, a control system can select either the series or the parallel mode, whichever offers greater efficiency. The motor speed can be varied to control the capacity of the compressor in either mode.

This work was done by Daniel L. Fischbach, Russell Tetreault, Andrew C. Harvey, William Leary, Nathan Longo, and David H. Walker of Foster-Miller, Inc., for **Johnson Space Center.** *MSC-22888*

Closed/Momentary-Opening/Closed Solenoid Valve

A poppet would be toggled between two "closed" positions.

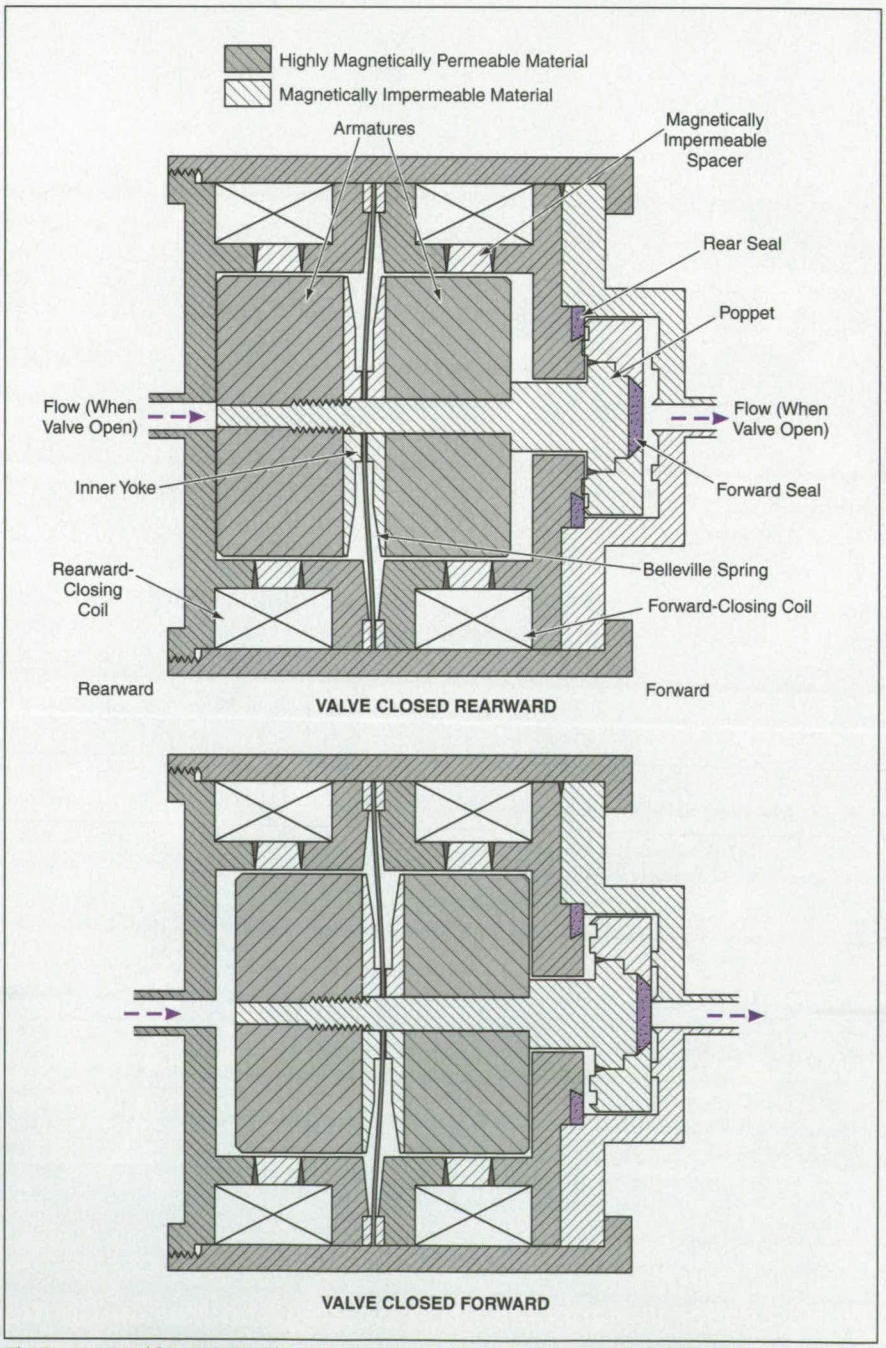
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed solenoid-actuated valve would open for a short time to pass a very small quantity of fluid. The valve could be used to meter a specified total quantity of the fluid through repeated actuations.

In the operation of a typical solenoid-actuated, momentary-opening valve of older design, the solenoid is first actuated to magnetically pull a poppet away from a valve seat to effect opening. Shortly thereafter, the current in the solenoid is turned off, allowing a spring to halt the motion of the poppet away from the seat and then push the poppet back into the seat to effect closure. In the proposed valve, there would be no return stroke; instead, to effect momentary opening, the poppet would be toggled between two "closed" positions. One advantage offered by this approach would be that without a return stroke, a shorter opening time could be achieved. Another advantage would be protective redundancy; if a leak were detected with the poppet in one of the two "closed" positions, one could simply switch the valve to the other "closed" position.

In the proposed valve (see figure), a poppet would be spring-loaded and latched into either a rearward or a forward "closed" position. The spring-loading and latching action would be effected by a Belleville spring, which would be stable in either "closed" position and would snap ("oil-can") between the two stable positions when the poppet was moved through the middle position. Two armatures (magnetically permeable plungers) would be mounted on the poppet, separated by an inner yoke. There would be two solenoids; a forward-closing and a rearward-closing coil.

The armatures would be positioned, relative to the solenoids, to configure the magnetic-flux paths to obtain the desired magnetic forces. The configuration would be such that upon application of electric current to the forward-



The **Poppet Would Remain** in either the rearward or the forward "closed" position, except for brief intervals during which one of the coils was energized to move the poppet to the other "closed" position.

or rearward-closing coil, the resulting magnetic force would pull the poppet toward either the forward or the rearward "closed" position, respectively. When neither coil was energized, the force of the Belleville spring would hold the poppet in whichever "closed" position was reached most recently.

This work was done by George Yankura of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
NPO-20596

Myoelectric Teleoperation for Robotics and Prosthetics

Thus far, it has been possible to distinguish myoelectric signatures of two different grips.

Lyndon B. Johnson Space Center, Houston, Texas

Johnson Space Center is sponsoring continuing research on the use of myoelectric signals to control dexterous robotic and prosthetic hands. This research is expected to advance the state of the art beyond that of today's most common, commercially available, myoelectrically controlled prosthetics — clawlike devices, little altered since the 1970s, that are restricted to motion in one degree of freedom and are basically motorized hooks. Thus far, the research has shown that by use of a suitable combination of electronic hardware and software, it is possible to recognize the myoelectric signatures of at least two different grips in real time, with an accuracy of at least 90 percent. While this level of performance is below the nearly 100-percent accuracy required for highly precise teleoperation (e.g., for controlling remote manipulators on the Space Station), it is high enough to offer potential benefits to the prosthetics community, and hence would be well worth further investigation. The fruits of this research might eventually include comfortable, lightweight, and relatively inexpensive prosthetic hands that could act, in a nearly lifelike manner and in real time, in response to the myoelectric signatures of as many as six different grips.

Experts in prosthetics generally agree that the following five types of grips are vital to a person's daily activities:

- The three-jaw chuck or pincher grip, used to hold small objects;
- The lateral or key grip, used to hold and actuate a key in a lock;
- The hook grip, used to carry an item like a book or a briefcase;
- The spherical grip, in which the thumb and fingers are wrapped around a sphere; and
- The cylindrical grip, in which the thumb and fingers are wrapped around a cylinder.

The designs of majority of commercially available electrical hand prostheses generally address the need for only a couple of these types of grips, and do not provide for independent control of fingers and thumbs. Most are capable of chuck grips only. Designs of the most advanced research models have provided for chuck and key grips, with options for spherical and cylindrical grips provided through passive compli-

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22mm motor shown with planetary gear box. Actual size.

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ance of fingers. All of these devices, at whatever level of sophistication, present control and interface problems.

One of the problems is caused by the fact that available myoelectrically controlled hands are limited to one-degree-of-freedom performance, although some offer proportional gripping forces as well. Worse yet, the most complex artificial hands are significantly larger and heavier than are human hands, and therefore amputees experience difficulty in controlling them. Indeed, the human hand is a complex mechanism that has 27 degrees of freedom and is capable of a wide range of powerful and yet delicate movements with quick, quiet, and smooth operation while exhibiting both high performance and efficiency. Therefore, it has long been thought that, given constraints on size and weight, it is well nigh impossible to design an artificial hand that performs at the level of the human hand. However, as has now been shown by the research reported here, it may be possible to construct a prosthetic hand that has multiple degrees of freedom and that performs the key motions of a human hand under control by processed myoelectric signals.

In this research, attempts were made to recognize, in real time, the myoelectric signatures of as many as six different grips by use of frequency (and, alternatively, time-frequency) techniques that "split" the signatures and by use of artificial neural networks to recognize the signatures. The development of an ability to distinguish among different grips would be a critical extension of the state of the art, inasmuch as commercially available myoelectrically controlled prostheses recognize only two usual states, i.e., "grip" and "open." In the research, various degrees of accuracy of recognition were obtained for various combinations of grips. The best results were obtained (accuracy >90 percent) in distinguishing between the chuck and key grips. Inasmuch as it was heretofore generally believed by experts in the field that it was not possible to extract grip-signature information from myoelectric signals, this is a significant achievement.

This work was done by I. D. Walker of Rice University for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
MSC-22940

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Formulation and Algorithm for Multi-Flexible-Body Dynamics

Subroutines can be executed independently at different frequencies to optimize computer performance.

Lyndon B. Johnson Space Center, Houston, Texas

An improved formulation of the dynamics of multiple flexible bodies coupled via joints, and an algorithm that implements the formulation, have been developed at Johnson Space Center (JSC). A robot arm with multiple, somewhat flexible links is a prime example of a dynamic system to which the formulation and algorithm are intended to be applied. Other potential domains of application could include spacecraft, aircraft, industrial, automotive, and marine systems. The goal in developing the formulation and algorithm was to increase the efficiency of computational simulations of the dynamics of all such systems.

Algorithms and computer programs that simulate dynamics ("dynamics simulators" for short) have become necessary for designing and operating increasingly sophisticated systems — especially in the case of spacecraft. As simulated systems become more sophisticated and more complex (thus increasing the amounts of computation needed to simulate their dynamics), increases in computational efficiency are needed to keep computation times as short as possible.

For More Information Circle No. 609

Prior dynamics simulators, of which there are many, can mostly be characterized as belonging to either of two general methods: the recursive Newton-Euler (NE) or the recursive projection (Lagrange-Kane) method. An attempt to base a dynamics simulator on either method results in inherent computational inefficiency for either a flexible- or a rigid-body problem for the following reasons:

- The recursive projection method also requires, among other things, the computation of a system-level mass matrix. In the case of a flexible-body problem, a system-level mass matrix is necessary for finding eigensolutions and for performing the modal truncations necessary to reduce computation time sufficiently for real-time applications. Therefore, the recursive projection method is better suited for a flexible-body problem. On the other hand, because the recursive projection method requires a system-level mass matrix even though such a matrix is not needed to solve a rigid-body problem, it is less computationally efficient when applied to such a problem.
- The recursive NE method does not require the computation of a system-level mass matrix and, because it does not, it cannot be used by itself to solve a flexible-body problem. On the other hand, because it does not require a system-level mass matrix, it is more computationally efficient for solving a rigid-body problem. In order to be able to apply the recursive NE method to a flexible-body problem, it is necessary to perform additional computations to construct the system-level mass matrix.
- Each of the recursive Newton-Euler (NE) and recursive projection (Lagrange-Kane) methods requires (1) both an inbound and an outbound recursion pass and (2) incorporation, into each dynamics simulator, of a tree-branch-indexing scheme to track the inbound and outbound recursions.

Unlike the formulations of recursive NE and recursive projection dynamics simulators, the formulation of the JSC dynamics simulator is based solely on body-to-body relations. As a consequence, there is no concept of branches in the algorithm; instead, there is only the relation of the current body to the previous body, as specified in a list of bodies. As a further consequence, only one recursion pass is necessary.

In the JSC dynamics simulator, the base body of a given system structure can be fixed or free. Each subsequent body, if any, can be attached to its parent body via joints characterized by any combination of 3 rotational or 3 translational degrees of freedom. Each body in the system can be wholly or partly rigid or flexible in any one or all of three dimensions.

The JSC dynamics simulator is designed to partition data and associated computations for multiprocess, multifrequency computation: The algorithm includes a set of subroutines that can be executed independently, at different frequencies, to optimize the computational performance in a given application. All of the subroutines work together to produce a complete dynamical solution, but computation time can be reduced, at the cost of lower fidelity, by lowering the frequencies of execution of some subroutines or not calling the subroutines at all.

In the JSC dynamics simulator, the number of operations to compute the coefficients of a mass matrix has been reduced significantly, relative to the corresponding numbers from all prior dynamics simulators; because of this and because all operations to construct a mass matrix and forcing-function terms are performed recursively, the execution time is reduced tremendously. As applied to a given flexible-body problem, the JSC dynamics simulator requires only about one-third as many computations (additions and multiplications) as do dynamics simulators based on the NE and projection methods applied to the same problem.

The JSC dynamics simulator relies on the proven symmetry of the mass matrix of a dynamic system to facilitate computation of elements in the upper left portion of a system mass matrix — elements that pertain to cross-coupling between rigid- and flexible-body dynamics and that are not easily computable in terms of the lower left portion of the mass matrix. This feature is an essential part of the mathematical justification of the single-pass recursion scheme.

The JSC dynamics-simulator formulation and algorithm have exceeded expectations at JSC, where computation times for simulations of the flexible-body dynamics of the space-shuttle remote manipulator system (RMS) have been reduced significantly below those of a dynamics simulator based on the recursive projection method. Similar reductions in computation time are anticipated for other applications.

This work was done by An Huynh of LinCom Corp. for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

MSC-22814

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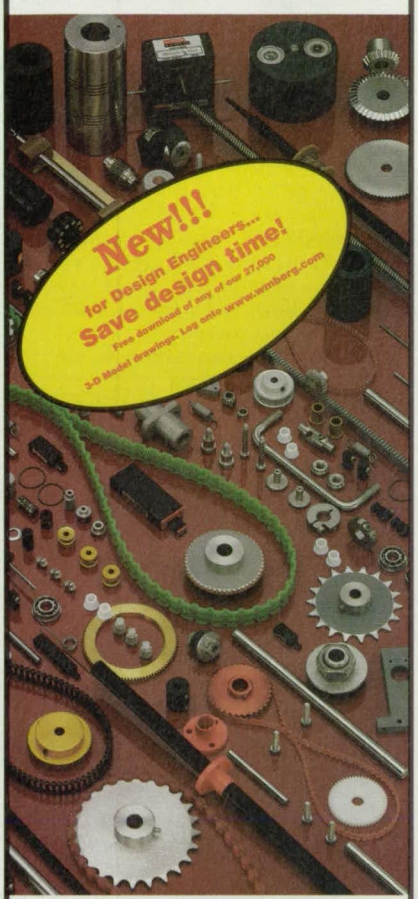

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For More Information Circle No. 610

NEW PRODUCTS

Profile Rail System

Lee Controls Inc., Piscataway, NJ, adds to its product line the SBC Profile Rail System, designed for use in automated production lines, CNC machines, power transmission, and any linear motion application where high precision and compact size are required. The system consists of LG series rails and LG series blocks that are available in four ranges, two for high load capacities and two for ultrahigh load capacities. Standard lengths begin at 6.5 in.; maximum length of a single rail is 120 in. The company says that the system's two-point ball contact design of the block and rail assures smooth movement.

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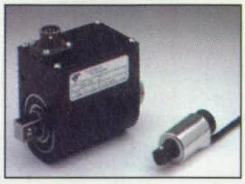

NIST-Traceable Torque Sensors

Transducer Techniques Inc., Temecula, CA, offers the RSS (rotating) and the SWS (reaction) torque sensors. Available in ranges of 10-1000 ft. lbs., they provide measurement of bolt or nut wrenching torques. Both are bidirectional, so that tightening and break-away torques can be measured, according to the company. Rated outputs for both are 2 mV/V, with accuracies of nonlinearity 0.25 percent, hysteresis 0.25 percent, and nonrepeatability 0.1 percent. The company says that the sensing element incorporates bonded foil strain gauges of the highest quality.

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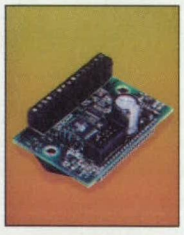


Analog Speed Control Board

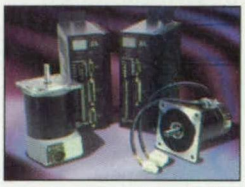
Intelligent Motion Systems, Marlborough, CT, announces the OSC-462H analog speed control board. It features a digital oscillator for accurate velocity control with an output frequency of up to 100 kHz, which will vary with the level of the 0-to-±5 V DC input via a 10-kOhm potentiometer. The speed control board is programmable using a 10-command instruction set of 2- to 7- character mnemonics. A single +12-to-+40-V DC supply provides power for both the OSC-462H and its IMS IB462H half/full-step ultraminiature hybrid step motor driver.

For More Information Circle No. 771

In-Line Flowmeter

The FlexMASSter® ST98L in-line flowmeter from Fluid Components International, San Marcos, CA, combines a wide flow range with accuracy and a streamlined feature set suited for low-flow gas measurement, according to the company. The device measures air flow from 0.0062 to 1850 SCFM to an accuracy of ±1 percent of reading plus ±0.5 percent of full scale, and its repeatability is ±0.5 percent. The no-moving-parts sensing element comprises two all-welded 316 stainless steel thermowells that protect resistance temperature detectors (RTDs). The in-line flow tube comes in a 1-in.-diameter tube or 1-, 1.5-, or 2-in. schedule 40 pipe.

For More Information Circle No. 774



Brushless Servos and Steppers

GE Fanuc Automation, Charlottesville, VA, offers a new family of brushless servo and stepper modules. The S2K Series is available in servo amplifier, servo controller/amplifier, and stepper controller/amplifier versions. All S2K Series controllers are available with standard DeviceNet™ communications and implementation, including ODVA-compliant master/slave messaging services and peer-to-peer support for multiaxis standalone systems. Other features include multiple speed position moves, index and phase synchronization, secondary position feedback, and digital and analog I/O.

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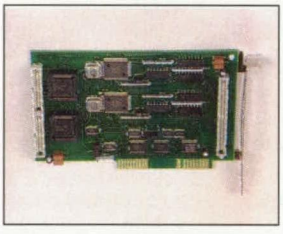

Four-Axis Stepper Motor Controller

Nippon Pulse Motor Co. Ltd., Radford, VA, announces the NPMC-5023-4ISA four-axis stepper motor controller, a control board that uses a high-speed PCL-5023 pulse generator chip. Key features include ISA-bus, 4-axis, high-pulse-rate capability of 4.9 M pps for microstepping, S-curve ramp-up and ramp-down, encoder feedback inputs, and linear interpolation. Software using Microsoft Windows helps provide quick setup and testing, the company says.

For More Information Circle No. 769

Mechanical Engineering Software

Algor Inc., Pittsburgh, PA, has added capabilities to its Mechanical Event Simulation (MES) software, providing new ways to impose motion during analysis of mechanisms and joints. The company says that new capabilities provide engineers with the freedom to rotate actuator elements and apply stop-and-start motion to finite element analysis models. Through the use of actuator elements, prescribed rotations, and prescribed displacements, Algor says its Accupak/MES and Accupak/VE analysis packages will enable engineers to simulate more realistic and functional mechanisms and joints.

For More Information Circle No. 772

Digital Force Gauge

Mark-10 Corp., Hicksville, NY, makes available what it calls the smallest digital force gauge on the market today. The 500-lb. Series MG measures 3.7 × 2.5 × 1.5 in. It offers a multifunction 4-½-digit LCD with a set of annunciators for peak force indication, units of measurement, and low-battery indication. It runs for 30 hours on a 9-V battery and automatically shuts off if not used. Sampling rate is 30 readings per second. It is available in several models covering the ranges from 0-0.25 lbs. to 0-500 lbs. Accuracy is ±0.5 percent, calibrated with weights traceable to NIST.

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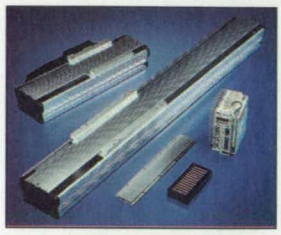

Linear Servo Actuator Series

THK America, Schaumburg, IL, introduces the linear servo actuator (LSA) Sabre Series. The company says that the series' "plug-n-play" design enables setup, from box to wired, in less than ten minutes. It operates at up to 4m/sec at 0.3-micron digitized encoder resolution (with the standard digital amplifier) and at forces up to 1080 N. Its linear encoder and magnets are fully enclosed for protection. THK says that extremely rapid accelerations are achievable, and the cable carrier is easily field-replaceable.

For More Information Circle No. 767

Single-Disc Servo Class Couplings

Zero-Max, Minneapolis, MN, expands its lines of servo class coupling with a new single-disc model in eight sizes with torque ratings from 8.84 to 885 in. lbs. The company says the servo class couplings feature zero backlash, flexible metal discs, and keyless clamp-type mounting hubs. The single-disc design, according to Zero-Max, provides a smaller package with greater torsional and axial stiffness than the current double-disc design counterpart. The eight models, designated SD010 through SD080, offer a range of operating torques and weights.

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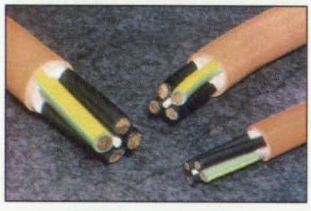

Severe Duty Motor Power Cables

C&M Corp., Wauregan, CT, introduces the FT4-certified severe duty motor power cables, which the company says can withstand exposure to chemicals, oils, abrasion, and extreme temperatures. Suitable for flexing applications, severe duty motor power cables can bear continuous motion and bending requirements in an automatic environment and do not need to be installed in conduits. The cables are available in a range of sizes, from 18 AWG to 1/0 AWG.

For More Information Circle No. 773

Robotic Seam Tracking Sensor

SenSolve Inc., Albuquerque, NM, has integrated its ST45 robot seam tracking sensor with the Motoman® MRC controller. The ST45 uses the company's proprietary fringing electric-field sensing technology to track part features during processes such as robotic arc welding. The sensors measure torch cross-seam position, height, and work angle in real time using the MultiDOF™ system to send corrections to the MRC controller. Welding torch position is automatically adjusted to eliminate errors due to fixturing or part tolerances. The ST45 also locates the seam starting position before arc initiation.

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FREE NEWSLETTER

Technology 2000

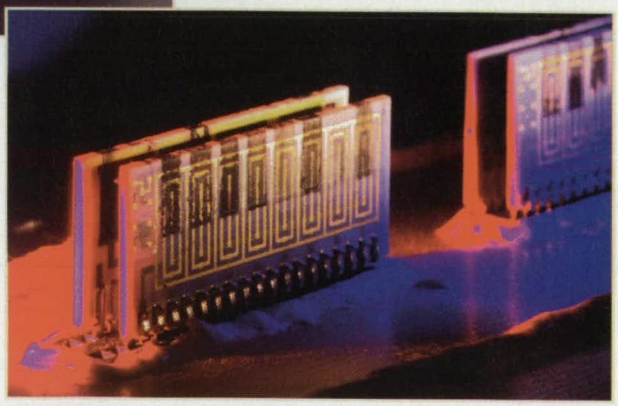
Technology 2000, the 11th annual conference for technology partnerships, licensing, and commercialization, will be held October 31 - November 2 at the Meydenbauer Convention Center in Seattle, WA. Last month, we focused on some of the innovative technologies that will be displayed by the Air Force Research Laboratory (AFRL) and NASA's Kennedy Space Center. Here, we showcase more of the latest technologies developed by the US Army, NASA, and the US Air Force.

Sponsored by NASA, *NASA Tech Briefs*, the AFRL, the Federal Laboratory Consortium Far West Region, and other federal agencies and industry partners, Technology 2000 will be held in conjunction with the third annual Small Business Tech Expo and the National Small Business Innovation Research (SBIR) Conference. For more information, visit www.T2Kexpo.com.

Golden Triangle of Technology

NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA; NASA's Ames Research Center, Moffett Field, CA; and NASA's Dryden Flight Research Center, Edwards, CA, will combine their technologies into an extensive exhibit that illustrates NASA's "Golden Triangle" of technology.

The Golden Triangle of Technology emphasizes that three important elements work together, as do the sides of an actual triangle, where any side can be the base, and where the sides intersect at the vertices of the triangle. The elements of NASA's Golden Triangle are biotechnology, nanotechnology, and information technology.



NASA JPL's quantum-well infrared photodetector (QWIP) camera uses highly sensitive focal plane sensor arrays that give it greater sensitivity, resolution, and stability than previous infrared cameras.

The three centers' exhibits underscore the interdependence of the sides of the triangle. In many cases, applications involve more than one of the technologies; for example, a bio-inspired use of chemical sensors, the bio-inspired application of polymers to the creation of an "artificial muscle," or the biologic applications of infrared photodetectors.

Biotechnology — The Quantum-well infrared photodetector, QWIP, is a camera that uses highly sensitive arrays in infrared photodetectors. The camera, developed at JPL, features a large-area, long-wavelength QWIP focal plane array that gives it greater sensitivity, resolution, and stability than previous infrared cameras. An application recently receiving clearance from the Food & Drug Administration (FDA) uses a QWIP sensor in a device called the BioScan System™, developed by OmniCorder Technologies of Stony Brook, NY. This application allows the non-invasive detection of breast cancer. Studies have determined that cancer cells exude nitric oxide, which causes changes in blood flow in tissue surrounding cancer. The digital sensor detects the infrared energy emitted, thus "seeing" the minute differences associated with blood flow changes. The JPL sensor also has been used in terrestrial applications such as locating hot spots during fires, and it has potential uses for search and rescue, spotting faulty welds and blockages, and volcano observation.

Also developed in a collaborative effort between JPL and Caltech is the Electronic Nose (ENose), which is designed to monitor the air quality in human habitats such as the Space Shuttle and the International Space Station. The electronic nose operates similarly to a human nose — both contain a large number of non-specific sensors. The JPL ENose is an array of chemical sensors made from 16 different polymer films. The polymers swell and shrink as the com-

position of the air changes, with these changes altering the electrical resistance of the films. Electronic Noses have been applied to environmental monitoring and quality control in such fields as food processing and medical diagnosis.

Developed at NASA Ames, S2K! (Sensors 2000!) is a high-performance workgroup that provides directed, advanced biosensor and bioinstrumentation systems technology in support of NASA's life sciences space flight and ground-based research and development. S2K! is developing pill-shaped biotelemeters for measuring physiological parameters during life sciences experiments aboard the International Space Station's Gravitational Biology Facility. Eventually, this family of devices could be used to monitor animal health parameters, and the performance of self-contained biological systems.

FutureFlight Central at NASA Ames is the world's only walk-in, full-scale, 360-degree airport simulator, allowing users to evaluate new tower positions, runway configurations, and aircraft movements before new construction begins.

Nanotechnology — Emerging nanoscience and nanoengineering advances will be showcased by NASA Ames. Focusing on the promise of this nascent field, the nanotechnology display will highlight carbon nanotubes, computational nanotechnology, biosensors, protein nanotubes, and computational- and opto-electronics.

The advanced miniaturization technology enables new science and exploration missions for which ultra-small sensors, power sources, communication, navigation, and propulsion systems with very low mass, volume, and power consumption are needed. Nanotechnology presents a new spectrum of opportunities to build device components and systems for entirely new space architectures that will reach the global commercial marketplace as well.

Information Technology — A new method and system for design optimization that incorporates the advantages of both neural networks and traditional response surface methodology has been developed at NASA Ames. The method employs a unique strategy called parameter-based partitioning of the given design space. In the design procedure, a sequence of composite response surfaces based on both neural networks and polynomial fits is used to traverse the design space to identify an optimal solution. Several illustrative applications of the method to aerodynamic design optimization will be shown.

Ames also will demonstrate FutureFlight Central, a full-scale airport operations simulator that has the look and feel of an actual air traffic control tower cab. Currently in use by San Francisco International Airport and Los Angeles International Airport, FutureFlight Central supports cost-benefit studies, provides a stable platform from which new requirements can be derived, enables information sharing among multiple users, and tests software performance, safety, and reliability under realistic conditions.

FutureFlight Central can be configured to support subsystems that may exist in some airport facilities, but not in others. The facility, located at NASA Ames, is the world's only walk-in, full-scale, 360-degree airport simulator, allowing users to evaluate new tower positions, runway configurations, and aircraft movements before new construction begins. The simulator's artificial world changes in real time, with weather changes and aircraft landing and taking off.

U.S. Army Technology Opportunities

The Team APG Business Development Office represents the U.S. Army's leading scientists, technicians, and analysts at the Aberdeen Proving Ground (APG) in Maryland. With more than 50 major organizations, 57,000 acres of instrumented test ranges and laboratories, and the capability to provide a broad range of technologies, Team APG is prepared to meet virtually any technical challenge.

Also represented at Technology 2000 will be the U.S. Army Soldier and Biological Chemical Command (SBCCOM), dedicated to developing, acquiring, and sustaining soldiers, soldier support, and biological and chemical defense technology, systems, and services. SBCCOM also provides for safe chemical weapons storage, environmental remediation, and domestic preparedness implementation. Many technology transfer opportunities exist for potential partners in cooperative ventures, and SBCCOM facilities are available for use in cooperative programs.

AFRL Research Highlights

From virtual reality to laser-propelled space vehicles, the Air Force Research Laboratory takes the Air Force's investment in science and technology and creates improved warfighting capability. Since 1997, the AFRL — the Department of Defense's largest laboratory — has pursued leading-edge technologies in such diverse areas as air vehicles and satellites; aero, rocket, and space propulsion; munitions and directed energy; sensors and information; materials; and training and protection. The AFRL will display some of the latest technologies from directed energy, human systems, information, materials and manufacturing, propulsion, sensors, and space.

True Integration Puts System-Level Simulation into Component-Focused CAD

Mechanical design simulation tools that are truly CAD-integrated deliver advanced simulation technology at an affordable price.

Savvy manufacturers competing in a global marketplace undoubtedly have invested in a myriad of software and hardware systems for computer-aided design, manufacturing, and engineering (CAD/CAM/CAE), as well as product data management (PDM) and enterprise resource planning (ERP).

Those same manufacturers probably have also spent tens of thousands of dollars on training, support, and maintenance of these computer resources — all with the aim of reducing time to market and improving quality in new product development.

In the design-for-manufacturing realm, an engineering team is likely deploying the latest mechanical design automation tools. New products are now created using realistic 3D solid models, which allow engineers to investigate the form and the fit of a design long before bending any metal or cutting any plastic in the prototyping phase.

This computer-aided approach already should be reaping important benefits for manufacturers. When a physical prototype of a design is finally built and tested, the parts usually fit, assembly interferences are less of a problem, and getting it right the first time is a realistic goal.

But after investing all of this time and money on the technology and support resources required, there's at least one critical question about a new mechanical system design that must wait to be answered by hardware prototypes: Does it work?

A new product that jams, breaks, or fails even after undergoing extensive design, testing, and production procedures is an expensive mistake that can cause a manufacturer to miss a critical window of market opportunity.

Getting Answers Early

Consider just these two new product examples: seat restraints for next year's vehicle designs and the latest cellular phone models. These products must meet mission-critical design requirements and stringent production schedules. If a manufacturer can't deliver quality products on time to demanding customers, there are plenty of competitors who can, and who will. And this cold, hard reality probably holds for most manufacturing industries.

Why let it happen? The smart approach is to address issues of functional performance early in the design cycle — at the same time the form and fit of a design is investigated and perfected. In this way, design mistakes can be found and corrected when the cost of addressing them remains low.

The bottom line is this: If one has the right tools to investigate the functional performance of a design at the same time its form and fit is evaluated, one would have all of the pieces needed to start truly realizing the long-promised time-saving, cost-cutting, and quality-improving benefits of digital product development.

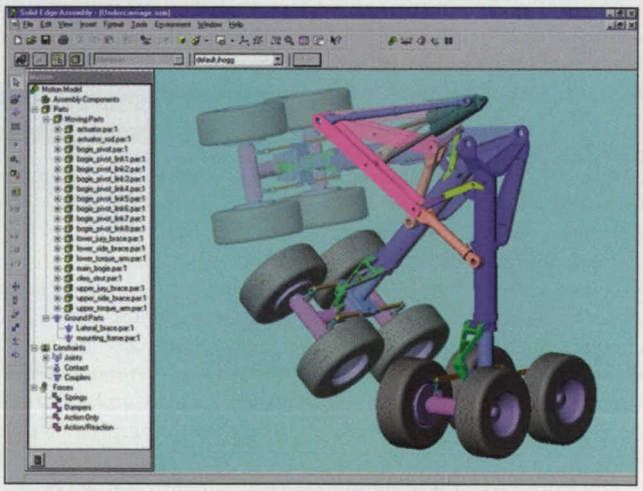


Figure 1: Dynamic Designer mechanical design simulation tool from Mechanical Dynamics is integrated inside Unigraphics Solutions' Solid Edge CAD software.

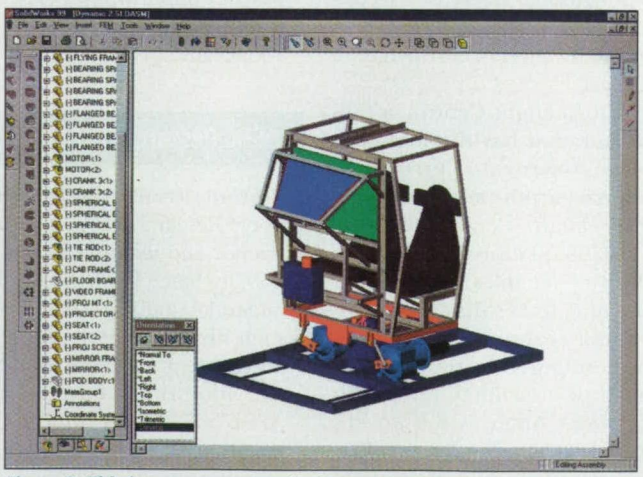


Figure 2: This image was created using Dynamic Designer seamlessly integrated with SolidWorks 99 CAD software from SolidWorks.

Proven Simulation Technology

Available today is CAD-embedded mechanical design simulation technology that's fully up to the task of answering the "does it work?" question. The most sophisticated of these software solutions also provide information needed to answer another important question about a design: Will it break?

The underlying technology for these products was developed more than two decades ago and has gained widespread acceptance by large companies' engineering teams developing complex products such as automobiles, aircraft, and space vehicles. These organizations have learned that by investigating the functional aspects of their designs on the computer, before building expensive physical prototypes, they can deliver better new products to market faster. At the same time, they have been able to reduce their overall development costs while evaluating many more design alternatives than before.

Today's mechanical design simulation products take design geometry created in CAD in the form of wireframe, surfaces, and solids that represent an assembly of moving parts. The user can then add special motion-related items such as joints, springs, motion generators, and forces to produce a complete motion model. The user simulates the assembly's motion over a period of time, calculating the displacement, velocity, acceleration, and reaction forces for each part in the assembly. This information can be used to produce animations and calculate interference ("Does it work?").

Mechanical design simulation also can generate operating loads needed for structural analysis ("Will it break?") using finite element analysis (FEA) software. In this way, the technology serves as a valuable complement to FEA.

CAE tools that are truly CAD-integrated — not just stitched on through clumsy interfaces for exchanging design geometry between software packages — deliver the same advanced simulation technology at a price affordable by even the smallest manufacturing organization or engineering workgroup.

What's more, since designers call up the simulation software's functionality from directly within their familiar CAD environment, they get answers to their design performance questions without having to learn new software or taking extra steps to transfer data.

Preserve as You Upgrade

There are embedded mechanical design simulation solutions for high-end CAD environments (such as CATIA, I-DEAS, Unigraphics, and Pro/ENGINEER), as well as for the most popular mid-range CAD systems (Autodesk Mechanical Desktop, SolidWorks, and Solid Edge).

In the mid-range arena, CAD-embedded simulation software provides increasingly sophisticated answers to the "Does it work?" question. One easily can upgrade within the product family, and as the upgrade is done, a manufacturer preserves its investments in training and previously created information because all of the products share a common user interface and data structure, and all interact with the CAD system in the same manner.

The most basic CAD-embedded mechanical design simulation software allows functional evaluation of designs containing linkages, motors, actuators, springs, and other basic components. Designers create realistic animations of their mechanical assemblies in operation, then check for interference among all components.

More advanced solutions allow designers to evaluate assemblies with added complexity, including cams, gears, latches, and contact. Designers not only can create animations and detect moving interference, they also can obtain basic performance information such as linear and angular displacements, and part velocities and accelerations. These data can be studied graphically and through XY plots.

The top-of-the-line CAD-embedded mechanical design simulation software provides capabilities at the next level, allowing designers to size motors and actuators, determine power consumption, and generate loads for FEA. This gives a design team the most complete answer to the "Does it work?" question, while also providing structural analysis data critical to determining "Will it break?"

For more information, contact the author of this article, Alan Wegienka, director of the Design Technologies Division of Mechanical Dynamics, Ann Arbor, MI; Tel: 734-994-2500; or visit www.designtechnologies.com.

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MDICE: Software System for Multidisciplinary Computing

Programs for different disciplines can readily be incorporated as needed.

John H. Glenn Research Center, Cleveland, Ohio

The Multi-Disciplinary Computing Environment (MDICE) is a software system for multidisciplinary analysis of complex engineering equipment, processes, and systems. Currently MDICE supports a variety of disciplines, including parametric computer aided design (CAD), grid generation, computational fluid dynamics (CFD), computational structural dynamics (CSD), active controls, and visualization/animation.

MDICE has been developed by CFD Research Corporation with funding from NASA Glenn Research Center and AFRL Air Vehicles Directorate at WPAFB.

While the growing need for multicomponent and multidisciplinary engineering analysis has been understood for years, lack of integration among computer programs that serve different disciplines has posed a major obstacle to such analysis. The existence of many different formats for the various data files contributes to the general difficulty. The development of MDICE has addressed those issues.

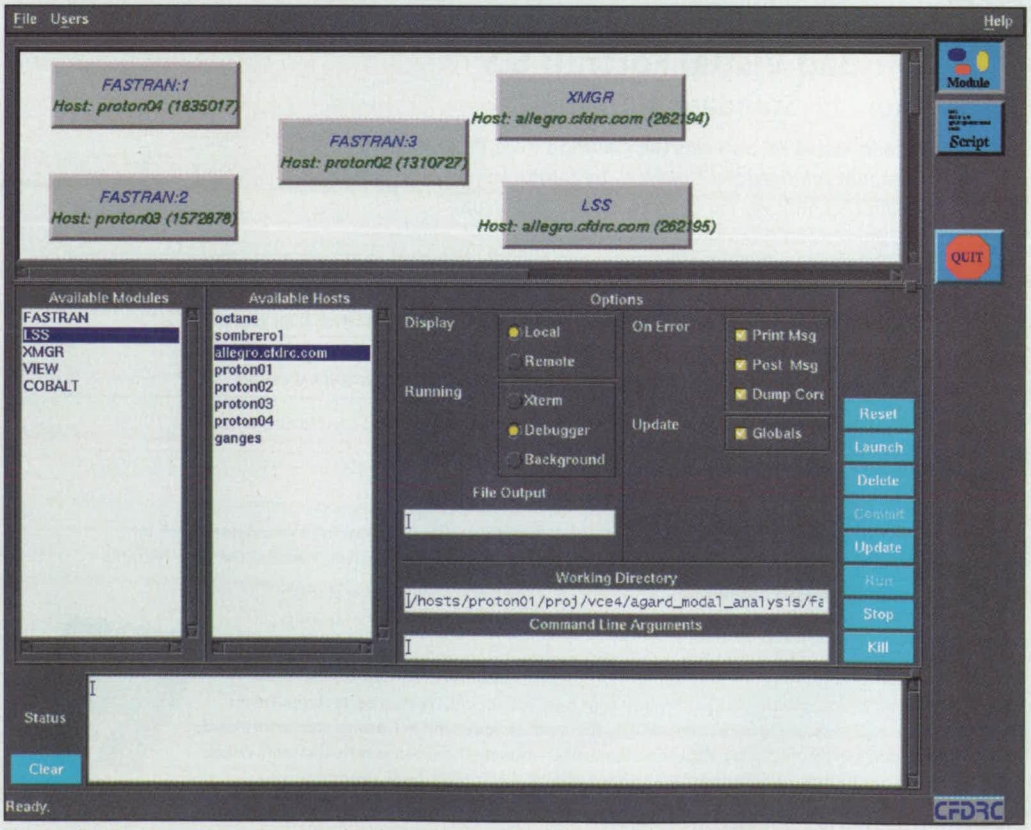
MDICE is an extensible program suitable for integration of analysis programs from several engineering disciplines. MDICE was developed by extending a prior software system, called "Visual Computing Environment" (VCE), that had been developed to enable coupling among various flow-analysis codes. VCE has been used with success in analyzing aircraft-engine components. The MDICE system is currently being applied to a large variety of multidisciplinary analysis problems for aerospace applications. Other application areas, such as automotive, electronics, manufacturing and MEMs design, are under development.

The MDICE approach is to provide a computing environment in which many computer programs operate concurrently and cooperatively to solve a multidisciplinary problem. Execution of each computer program is controlled by an engineer via a graphical user interface generated by MDICE (see figure). Once running, these programs communicate with each other and with MDICE via a set of standard function calls. Like the execution of each program, the management of the communications among the application programs is fully controlled by the user. MDICE takes care of all data transformations necessary for data exchange between dissimilar applications and disciplines.

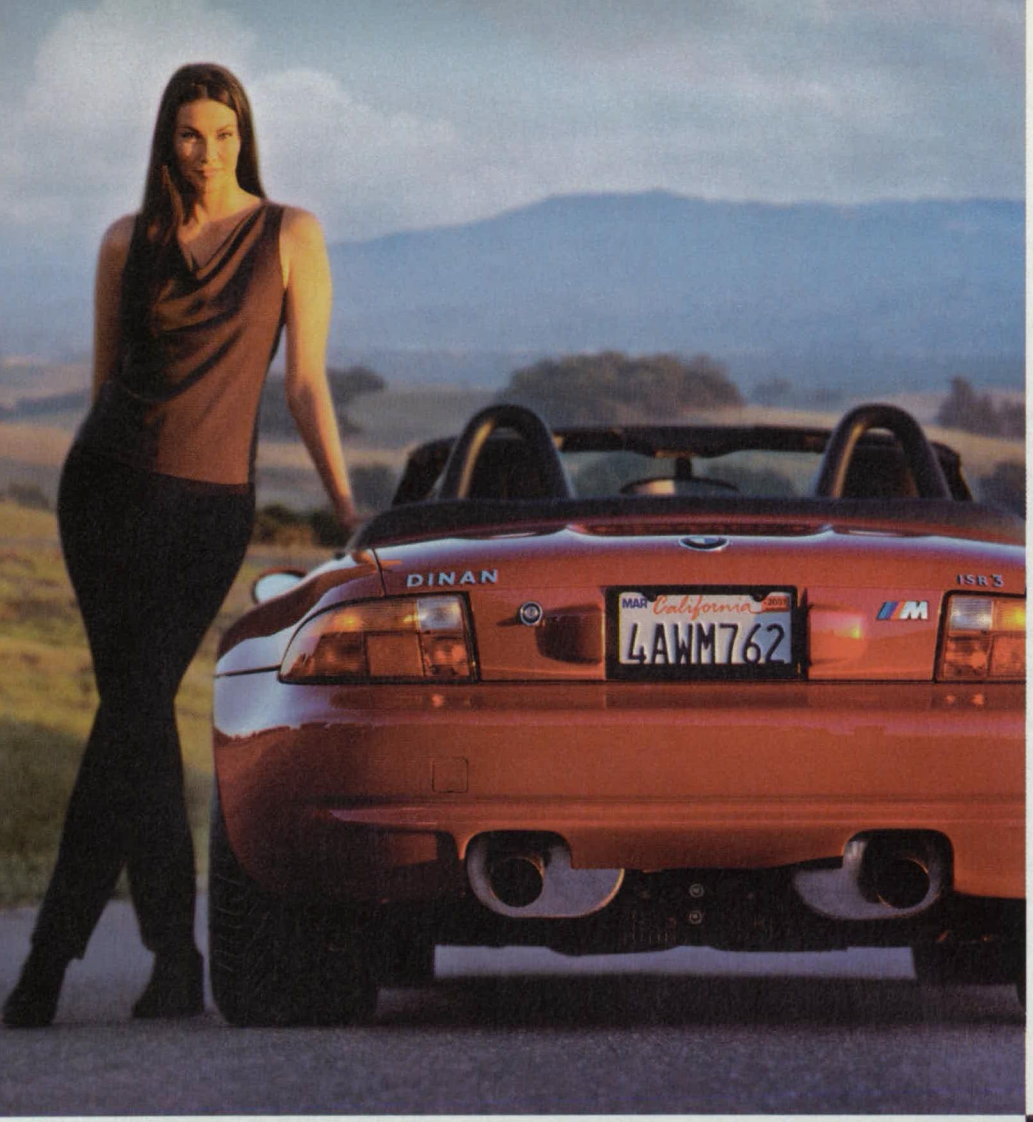
Integration of a particular application program into the environment is accomplished by making the application MDICE-compliant rather than writing the code to communicate with a small set of other, predetermined programs. An MDICE-compliant application program can run under the control of MDICE and communicate with any other MDICE-compliant application program.

The use of MDICE makes it possible to avoid the need for a giant, monolithic code that one might otherwise attempt to develop to provide all the services needed in a given situation. Such large programs are difficult to develop and maintain and, by their very nature, tend not to be up to date. The MDICE approach both accommodates and relies upon the reuse of previously developed codes that have been validated and have a high level of end-user familiarity.

The MDICE environment enables flexibility in that one can readily exchange one application



The **Application Control Panel** is a graphical user interface for setting up and controlling a computational simulation. Through this interactive display, a user can select an application program, select the computer on which the application program is to be run, specify a directory in which the program is to be run, and specify any command-line arguments that might be required by the program.



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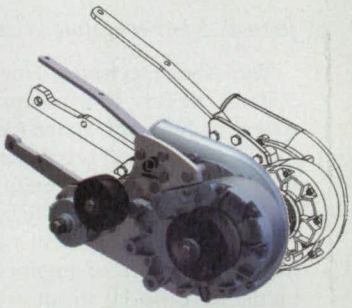

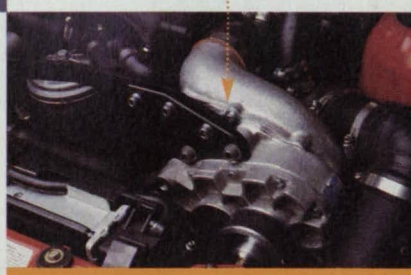

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program for another; thus, each engineer can select and apply the software best suited to the task at hand. Efficiency is achieved by use of parallel, distributed computing architectures utilizing heterogeneous software and hardware. Extensibility is achieved by providing for the addition of new application programs without modifying or deleting application programs that have already been integrated into the environment.

A large number of engineering analysis programs from a variety of disciplines and sources have been integrated with MDICE. Examples for CAD are CFD-GEOM (CFDRC), Unigraphics (Unigraphics Solutions), and Pro/ENGINEER (Parametric Technology Corporation). CFD applications include CFD-ACE, CFD-ACE+, CFD-FASTRAN (all CFDRC), NPARC, ADPAC, CORSAIR (NASA Glenn), Cobalt, ENS3D-AE (AFRL), CGNSfv (Northrop Grumman), Splitflow (Lockheed Martin), and others. Structural analysis codes include FEMSTRESS (CFDRC), NASTRAN (MacNeal Schwendler Corp.), and ANSYS (Ansys Inc.).

Typical applications include multifidelity, multidimensionality, and multicomponent CFD analysis, fluid-structure interaction, parametric geometry and analysis, active controls, and in general any application involving moving and deforming computational grids. Planned applications include optimization, aero-servo-elasticity, and aero-thermal-elasticity.

This work was done by Charles Lawrence of **Glenn Research Center**; *Vincent J. Harrand, Gerry Kingsley, and John M. Siegel of CFD Research Corp.; and Joel J. Luker of the Air Force Research Laboratory. For further information, visit CFDRC's MDICE website at www.cfdrc.com or access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

LEW-16830

Electronic Storage and Retrieval of Engineering Documents

Drawings can be retrieved from a remote central site, manipulated, and printed locally.

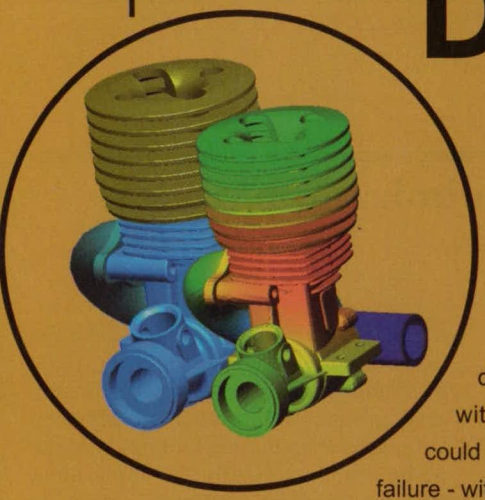
John F. Kennedy Space Center, Florida

The KSC Electronic Documentation System (KEDS) is a computer-intranet system at Kennedy Space Center (KSC) for the storage and retrieval of engineering drawings and other engineering documents that have been officially released. Prior to the development of the KEDS, microfilm copies of engineering documents were stored in an archive at the Engineering Document Center (EDC) in the KSC headquarters building; engineers and drafters had to travel from remote sites to the EDC to view microfilm images of drawings, and the cost of fulfilling requests for documents (including printing paper copies) was considerable.

The KEDS makes it possible for customers at remote locations equipped with personal computers running any Windows operating system to retrieve the documents via the World Wide Web (WWW), view the documents, and generate paper copies on their own computer printers. Microfilm copies of documents are mounted on Hollerith aperture cards that are punched with data that identify the documents. The aperture cards are then scanned to digitize the images and the resulting image data are stored on a scan-server computer. Once a document has thus been scanned into the KEDS, there is no further need to handle either the original paper copy or a microfilm copy other than to place it in the archive. Thereafter, requests for the document copies can be fulfilled from the scanned, digitized version of the document.

The KEDS document data are eventually transferred from the scan-server to a file-server computer, where they are stored in a read-only format. The file server is a DEC VAX computer located within KSC's Internet "firewall," which allows access by KSC personnel and other authorized customers only. The KEDS utilizes the standard Transmission Control Protocol/Internet Protocol (TCP/IP) for efficient transfer of electronic requests from, and images to, customers' personal computers. An application program for viewing KEDS scanned images was developed by, among other things, incorporating a commercial viewer program, with suitable regard for licensing requirements. The KEDS WWW home page provides a fully automated software-download feature, eliminating the need for costly technical-support visits to customer sites.

Don't Take Chances with your Designs



Will it overheat? Will the stresses be too high? Will it break? If you are designing your models without using analysis, you could be risking a potential part failure - without even realizing it. Don't take unnecessary chances with your design. Use COSMOS/ throughout the design cycle to help identify potential problems before it's too late.

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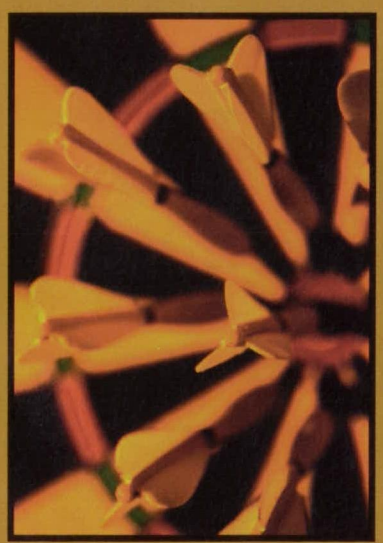

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A customer can gain access to the KEDS through any standard WWW browser program. Once the KEDS home page is displayed on a customer's computer screen, the customer can obtain instructions for downloading and configuring the KEDS viewer software. The KEDS server gathers identifying information entered by the customer via a download-request page; this information is stored in a data base. Once the customer has downloaded and configured the viewer software, the customer types in a number that identifies a package of engineering documents; in response, a list of available drawings and/or other documents is displayed. When the user selects the drawing sheet or other document from the list, the viewer software is invoked automatically.

The user software provides options for panning, zooming, rotating, printing, and cut-and-paste operations on a displayed KEDS image. By use of the cut-and-paste option, the image can be inserted easily into documents produced by other Windows-based application programs, including spreadsheet and word-processing programs. The standard Windows printer-interface forms can be used for local and/or networked printing of any view of a drawing.

This work was done by Donna L. Pancho, Richard Hall, and Dale L. Hirchert formerly of EG&G Florida, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11958.

Software Assists in the Development of Optimization Models

This program automates much of the model-development process.

John F. Kennedy Space Center, Florida

Optimization Modeling Assistant (OMA) is an expert-system computer program that assists its users in the development of mathematical and algorithmic models for optimization. As used here, "optimization" refers to a suite of powerful decision-support techniques that enable the modeling of any decision-making environment in terms of the objectives, the decisions that potentially influence the objectives, and a set of constraints that bind the decisions. Optimization analysis helps decision makers in identifying decisions that optimize their objectives. Domains in which optimization modeling are applied include real-time scheduling, logistics, planning, and financial management.

Unfortunately, difficulties inherent in the construction of optimization models have prevented the realization of the full potential of optimization modeling in these and other domains. These difficulties include the following:

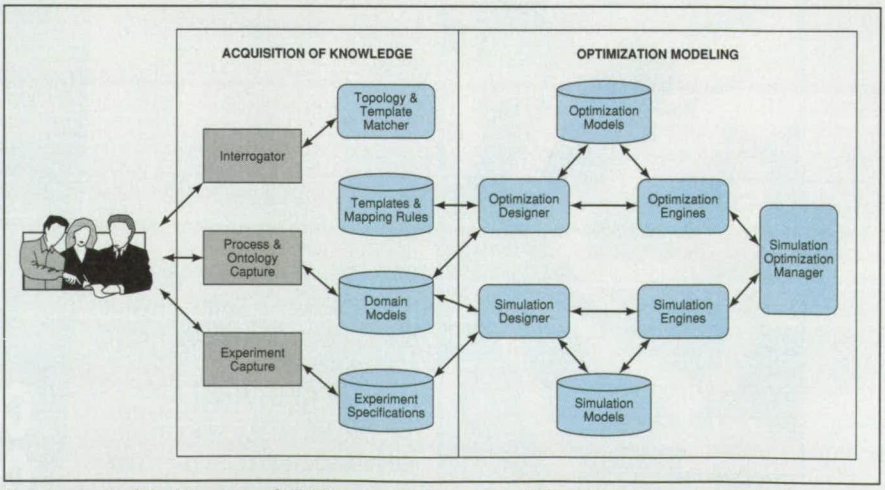
- Often, optimization models for a given domain address aspects of the domain that are invisible to casual observers.
- Optimization analysis is expensive because it demands highly specialized skills. A major hurdle is that domain experts are typically not expert in the techniques of optimization, and vice versa.
- Because of a lack of a comprehensive decision-support software environment, optimization-based decision-support systems typically depend on building custom solutions for different domain situations. It is often necessary to redesign such a system as the environment evolves or the requirements change.

OMA (see figure) helps to overcome the difficulties by utilizing knowledge-based-systems techniques to automate much of the model-design process. Though OMA can be used by itself, it is designed to be integrated into a more comprehensive decision-support software environment. OMA assists users in developing structured optimization models from possibly unstructured domain descriptions. The intended users of OMA include both domain experts and optimization experts who lack expertise in each others' specialties.

OMA reuses domain models to automatically generate optimization models. Domain models can be process models or ontology models. In a given application, OMA guides its user(s) through a step-by-step process, according to a structured methodology, to generate relevant and solvable optimization models from structured domain models. OMA extracts, from both the user(s) and the domain models, the information (e.g., goals and parameters) necessary for generating optimization models. OMA then automatically generates and validates the optimization models for the application. The results of the validation subprocess can be used to identify information missing from the optimization models, to identify unsatisfiable constraints, and to identify circular definitions.

The main benefits of using OMA include the following:

- Improved automated support for capturing domain-expert descriptions of systems, situations, and problems;
- Increased productivity in the selection of optimization techniques and in the design and execution of optimization models;
- Enhanced communication between domain experts and optimization analysts; and



The **Conceptual Architecture of OMA** accommodates two distinct processes — acquisition of knowledge and optimization modeling. The architecture is modular, so that OMA can evolve and be integrated with other decision-support software tools.

- Reduced dependence on optimization experts to design and use optimization models for decision-support activities.

This work was done by Perakath C. Benjamin, Satheesh Ramachandran, and Madhav Erraguntla of Knowledge Based Systems, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Perakath Benjamin
Knowledge Based Systems, Inc.
1408 University Drive East
College Station, TX 77840

Refer to KSC-12135, volume and number of this NASA Tech Briefs *issue, and the page number.*

Interface Program for Generation of Computational Grids

Marshall Space Flight Center, Alabama

Computer Aided Grid Interface (CAGI) is a computer program that serves as an interface between computer-aided design/computer-aided manufacturing (CAD/CAM) programs and computational fluid dynamics (CFD) programs. CAGI reads Initial Graphics Exchange Specification (IGES) files from CAD/CAM programs and converts from CAD/CAM geometries to nonuniform rational B-splice (NURBS) surfaces to be manipulated or written out in forms appropriate for generation of grids for CFD.

This work was done by Tzuyi Robert Yu and Bahrat Soni of Mississippi State University for **Marshall Space Flight Center**. *For further information, contact Larry Gagliano, MSFC Software Release Authority, at (256) 544-7175 or larry.gagliano@msfc.nasa.gov.*

MFS-31302

Software Predicts Impacts of Orbital Debris on Spacecraft

This program performs impact simulations faster than do conventional hydrocodes.

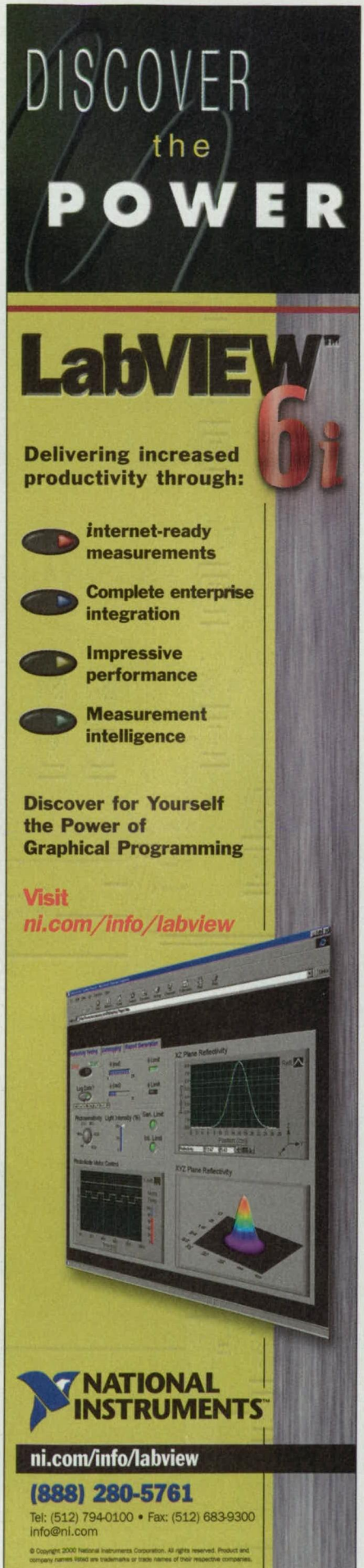
Lyndon B. Johnson Space Center, Houston, Texas

The EXOS computer program numerically simulates impacts of orbital debris on spacecraft. EXOS can be used to simulate meteoroid- and orbital-debris-impact damage to commercial satellites, and to simulate effects of weapons on personal and vehicular protection systems. With further development, the simulation technique employed in the EXOS package could be adapted for use in structural applications; for example, to simulate crashes in evaluating designs of vehicles.

EXOS includes a preprocessor subprogram, an analysis code, and a simple rezoner subprogram, for use in simulating large-strain thermoelastic-plastic continuum dynamics, including contact-impact effects. Commercial graphics codes are used to postprocess simulation data. EXOS implements a hybrid particle/finite-element method and is an alternative to prior Lagrangian, Eulerian, and particle-based impact codes.

In the present method, Hamilton's equations are applied to a system of translating, deforming, and thermomechanically interacting physical particles, to obtain a three-dimensional hydrodynamical model for shock-physics simulations. The method is energy-based and, hence, simple to formulate, with no need to consider continuum balance laws, interpolation functions, or weighted-residual solution techniques. Inasmuch as equations of particle kinematics, energy functions, and constraints are fully Lagrangian in form, the method makes it possible to avoid the diffusion problems typically associated with interpolation on space-fixed meshes and the stability problems observed in some moving interpolations.

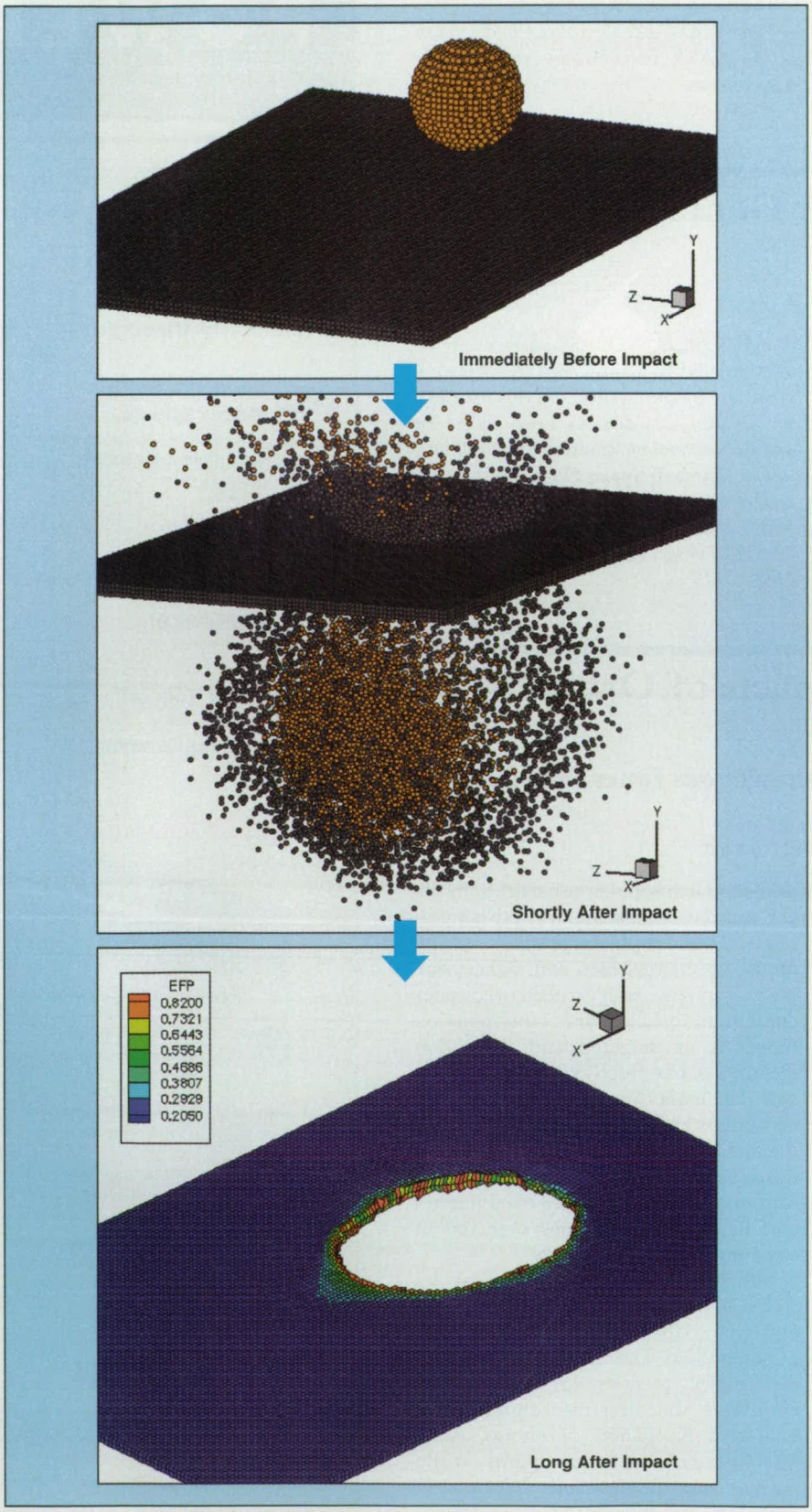
Although previous methods have involved limited use of entropy states, total-entropy variables appear in this method as generalized coordinates for the particles, subject to nonholonomic thermal constraints that describe conduction of heat and dissipation of energy. Additional nonholonomic constraints on the particle coordinates and deformation gradients are introduced to represent mechanical interaction of the particles;



For More Information Circle No. 411

this approach makes it possible to avoid the introduction of essentially Eulerian potential-energy functions or the remapping of data between the particles and a grid to quantify collision forces. Finally, the use of a fully Lagrangian frame of reference means that no mixing or partial pressures are needed to represent the multimaterial case.

EXOS is a three-dimensional implementation of the aforementioned particle method with an extension to include a finite-element-based description of material-strength effects, suitable for use in the simulation of hypervelocity impacts. In comparison with conventional continuum hydrocodes that have been used previously to solve orbital-debris-impact problems, EXOS is faster and more robust. Although numerous codes have been used in the past to simulate impacts of meteoroids and debris on spacecraft shields, in general they have proven very difficult to apply to three-dimensional simulations.



These **Images Are Results of a Computational Simulation** of hypervelocity impact of an aluminum sphere on an aluminum plate.

The figure presents selected results from an EXOS simulation of the impact of an aluminum sphere of diameter 0.953 cm on an aluminum plate of thickness 0.1143 cm at a speed of 6.56 km/s and an angle of 45°. The first image depicts the situation immediately before impact, the second image shows the situation 6.6 μs after impact, and the third image shows the resulting hole in the plate. The color contours depict accumulated plastic strain. The results of simulation have been found to be in substantial agreement with a radiograph taken in an experiment that corresponds to the simulation and that was reported in NASA Contractor Report 4707 (by A. J. Piekutowski, dated February 1996).

Johnson Space Center is working closely with the University of Texas to validate the use of EXOS in predicting the results of hypervelocity impacts on spacecraft shields. In the course of this verification process, EXOS has been modified and improved. The verification process was continuing at the time of reporting the information for this article.

Johnson Space Center is taking advantage of the stability and speed of EXOS to perform shield-impact simulations at its Hypervelocity Impact Technology Facility. Other agencies and companies involved in effects of hypervelocity impacts and protection of spacecraft could benefit from this code. With further development, its range of applications could be expanded.

This work was done by Eric P. Fahrenthold of the University of Texas at Austin for **Johnson Space Center**. *Further information is available in the article, "Hamiltonian Particle Hydrodynamics," by E. P. Fahrenthold and J. C. Koo, published in the journal Computer Methods in Applied Mechanics and Engineering, Volume 146 (1997), pp. 43-52.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Dept. of Mechanical Engineering
University of Texas
Mail Code C2200
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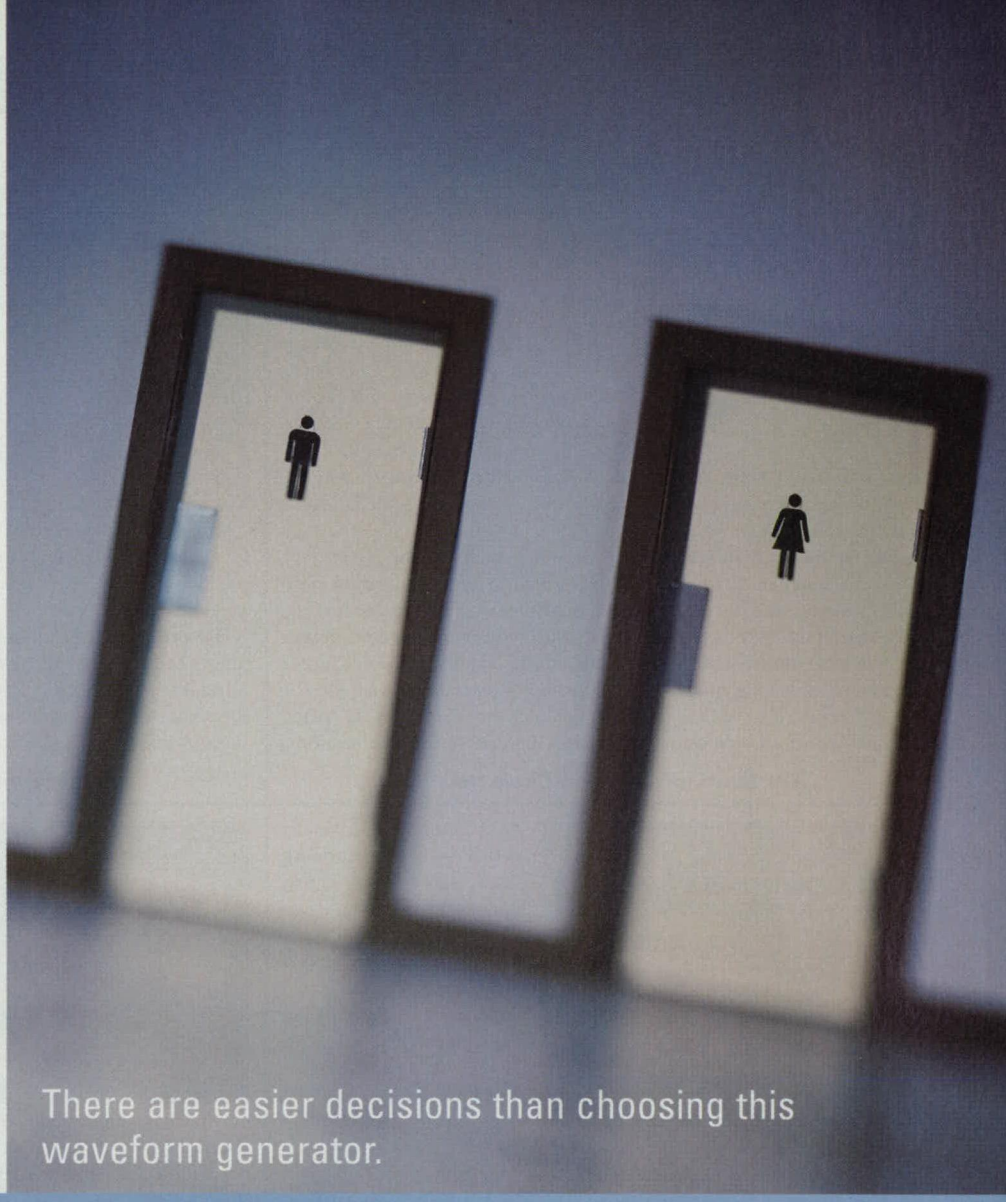
Austin, TX 78712

Refer to MSC-22979, volume and number of this NASA Tech Briefs *issue, and the page number.*



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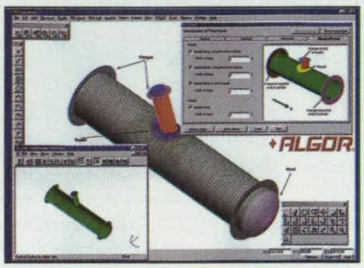
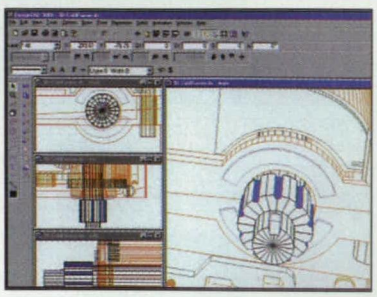


Algor, Inc., Pittsburgh, PA, has released PV/Designer **pressure vessel design software** that can be added to any Algor software package. It generates FEA models for pressure vessel and piping component analysis, enabling users to generate common intersecting piping or cylindrical structures. Models can be exported as a trimmed-surface IGES file.

The software features pop-up windows such as the Geometry Definition screen, in which the analyst can generate an entire pipe with a single intersecting cylinder or individual angular segments. The segments can be pieced together with other generated models in a CAD solid modeler. All settings are automatically saved so different variations of a component can be created, altered, and analyzed for what-if scenarios. Other features include the capability to place flanges at ends of segments, and reinforcing pads at the intersections.

For More Information Circle No. 711



Upperspace Corp., Pryor, OK, has released DesignCAD 3000 **2D/3D CAD software,** which provides 2D drafting and 3D modeling capabilities. The program features shading and rendering, with textures, texture-mapping, multiple independent light sources, and 3D animation. Drawings can be imported from and exported to a variety of graphic file formats. With VRML output, users can place a 3D model on web pages and allow others to view, rotate, and animate the drawing with a web browser.

The program's 3D modeling capabilities include solid subtraction, union, intersection, and interference checking. Solids can be created using linear extrusion, circular sweep, and patches. The software also supports multiple views of multiple files and is compatible with Windows 95/98/NT/2000.

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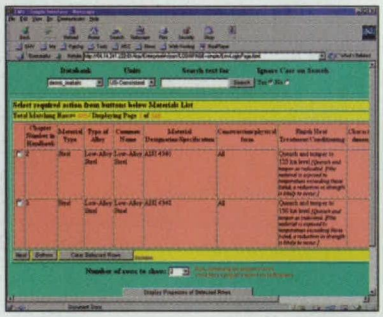

MSC.Enterprise Mvision web-based **engineering data software** from MSC.Software Corp., Los Angeles, CA, is a client-server software that enables users to retrieve a variety of engineering information for use with CAD/CAE programs via a standard laptop or PC and phone-line connection. The database product is part of the MSC.visualNASTRAN environment with web-based access that allows engineers to perform graph creation and manipulation, and create custom-formatted input data for analysis programs.

Applications include management of loads, CAE and damage-repair data, and publishing of searchable data on standard parts. Users can apply a variety of search mechanisms, as well as retrieve textual, graphical, numerical, or image data.

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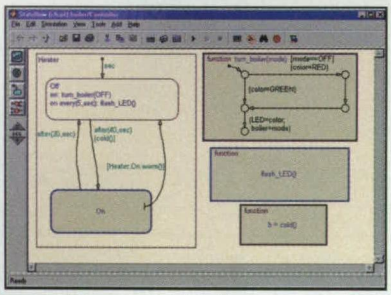

The MathWorks, Natick, MA, has introduced Stateflow® 3.0 and Stateflow Coder 3.0 **logic design software** for control and DSP engineers and embedded systems designers. Stateflow 3.0 allows users to incorporate temporal logic conditions into complex, event-driven embedded systems. Both programs employ an event-scheduling mechanism for code generation of event-driven systems. An additional enhancement is the ability to define functions using flow graphs.

Enhancements enable engineers to automatically generate high-structured, readable code. Other features include temporal conditions that express the time-dependent behavior of the systems, and full-featured subcharts. Both programs are available for Windows and UNIX platforms.

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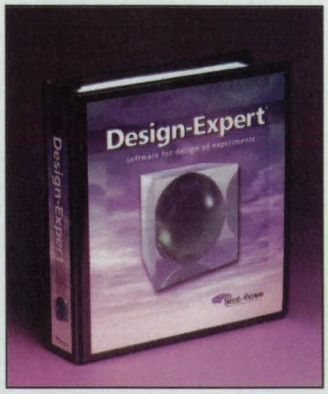

Design-Expert 6.0 **design of experiments software** from Stat-Ease, Minneapolis, MN, allows users to screen for vital factors, locate ideal process settings, and discover optimal product formulations. The release offers expanded design and analysis capabilities for mixture, process, and/or categorical factors. It also features six tools for generating and graphing propagation of error (POE).

The software includes a context-sensitive help system to simplify interpretation, and interactive graphics and plots to make response visualization easy. Optimization features allow users to maximize desirability for dozens of responses simultaneously.

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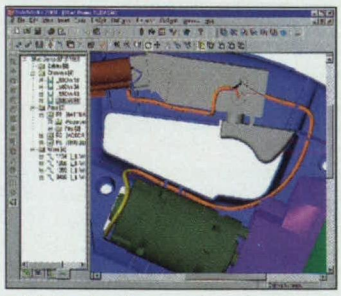

EMbassy Works **wire harness design software** from Linius Technologies, Westborough, MA, allows electromechanical assembly engineers to design and document wire harness and cable systems within the SolidWorks 3D CAD environment. It features harness path definition that enables efficient layout of harness and cable paths. Automatic calculations provide wire length and bundle diameter data in a format that is continually updated whenever the design changes.

By using Wire List Import capabilities, wires are automatically created by importing a configurable ASCII from/to list, or may be added or changed manually. EMbassy Works also includes manufacturing and back-end functions, like the optional EM~Nailboard and EM~Report modules to streamline the creation of manufacturing documentation.

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Tunable Terahertz Source Based on Near-Infrared Diode Lasers

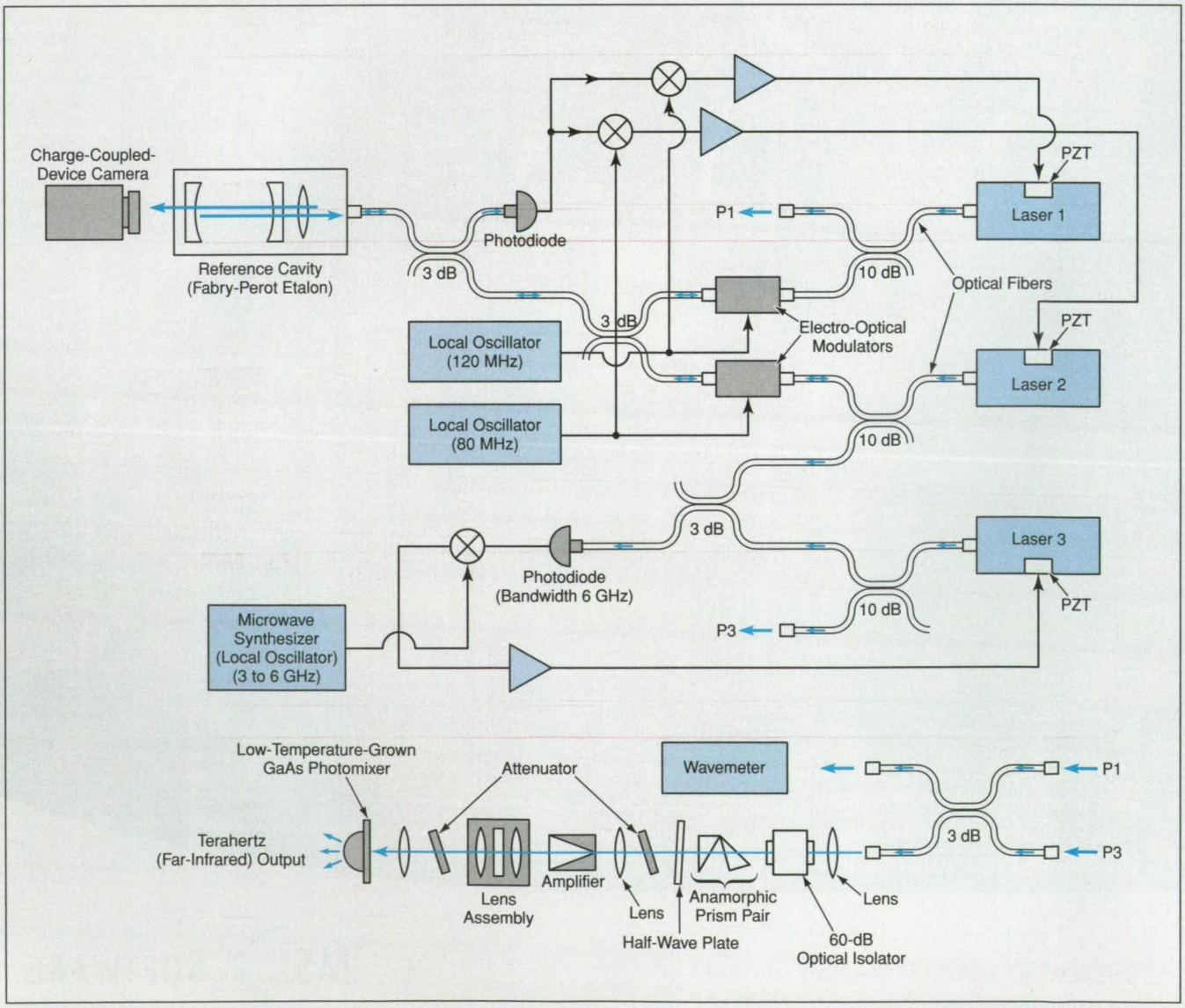
A far-infrared signal is generated by the heterodyne method.

NASA's Jet Propulsion Laboratory, Pasadena, California

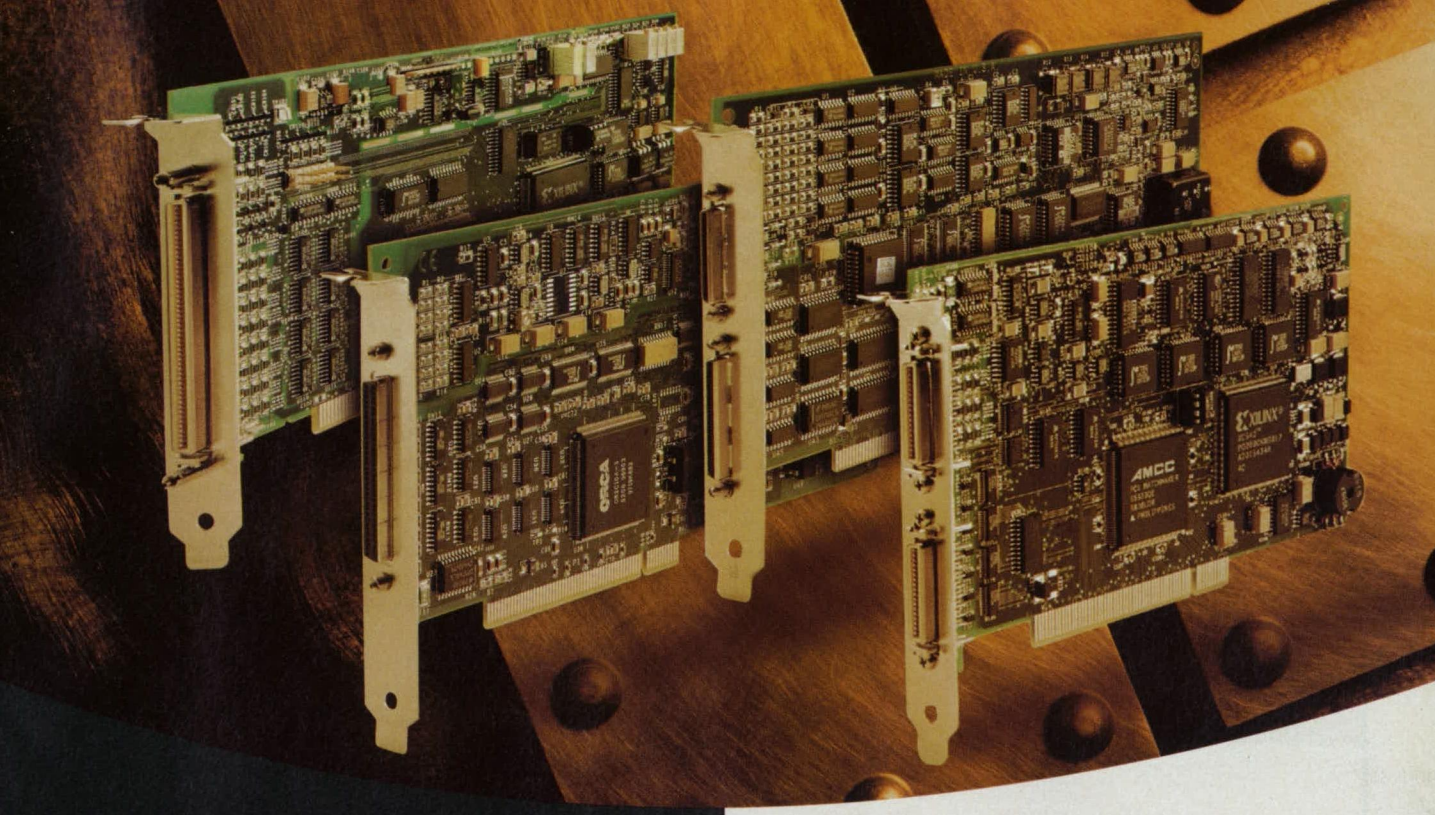
The figure schematically depicts a heterodyne photonic apparatus built around three continuous-wave, near-infrared diode lasers. This apparatus generates electromagnetic radiation at an adjustable, precisely defined frequency in the terahertz range. The spectral width of the signal is less than about 1 MHz. The apparatus could serve as a prototype of tunable far-infrared sources and heterodyne up- and down-converters for fiber-optic communication systems and for testing infrared systems in general. Other potential uses lie in infrared spectroscopy for remote sensing and in research on low-energy light/matter interactions.

The three diode lasers operate at wavelengths near 850 nm. Each diode laser is packaged with a collimating lens, a resonant-cavity assembly tunable in length (and thus in frequency) by means of a piezoelectric transducer (PZT), and other optics to circularize and couple the laser output to an optical fiber. All the optical components, including the optical fibers, are polarization-maintaining.

The three diode lasers are parts of a master-oscillator subsystem that generates two laser beams at different wavelengths near 850 nm. These beams are used for two-frequency injection seeding of a single semiconductor tapered optical amplifier. The output of the amplifier is fed to a photomixer, wherein the final output terahertz signal is generated. Thus, the overall photonic system can be character-



This **Tunable Heterodyne Photonic Apparatus** generates a spectrally narrow signal at precise frequency in the terahertz range.



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ized as a photomixer pumped by a photonic master-oscillator/power-amplifier (MOPA) subsystem. Typically, the system is operated at a power-amplifier output power level of 30 mW, yielding a terahertz output power of ≈0.1 μW. At present, the output level must be limited to prevent thermal failure of the photomixer; if this limitation could be overcome, then the power amplifier could be operated at its maximum output level of 500 mW, making it possible to generate about 10 μW of terahertz output.

The frequencies of lasers 1 and 2 are controlled by locking them to different longitudinal modes of a reference cavity in the form of an ultra-low-expansion (ULE) Fabry-Perot etalon. This is accomplished by the Pound-Drever-Hall technique, which is a frequency-modulation/optoelectronic feedback control technique for stabilizing the frequency of a laser. The frequency modulation for this purpose is effected through electro-optical modulators driven at frequencies of 120 and 80 MHz, respectively.

The difference frequency between lasers 1 and 2 is discretely selectable in increments equal to the free spectral range (FSR) of the reference cavity (increments of about 3 GHz). Laser 3 is heterodyne phase-locked to laser 2, offset in frequency by an amount established by a tunable microwave synthesizer that operates in the frequency range of 3 to 6 GHz. The difference frequency between the lasers 1 and 3 — the final output frequency in the terahertz range — is the sum of the microwave offset frequency and an integer multiple of the FSR of the reference cavity. The microwave offset frequency is locked to a reference source accurate to within a fractional error $<10^{-12}$. The accuracy of the final output frequency is determined by the accuracy of measurement of the FSR (within about ±50 kHz) and by any dc offset in the electrical portions of the lock loops. The ULE material in the reference cavity has a coefficient of thermal expansion of -2×10^{-10} $(°C)^{-1}$, resulting in frequency stability (with respect to temperature) comparable to that stability of a good quartz reference oscillator in a conventional microwave source.

This work was done by Herbert Pickett, John Pearson, Serge Dubovitsky, Pin Chen, Geoff Blake, and Shujii Matsura of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
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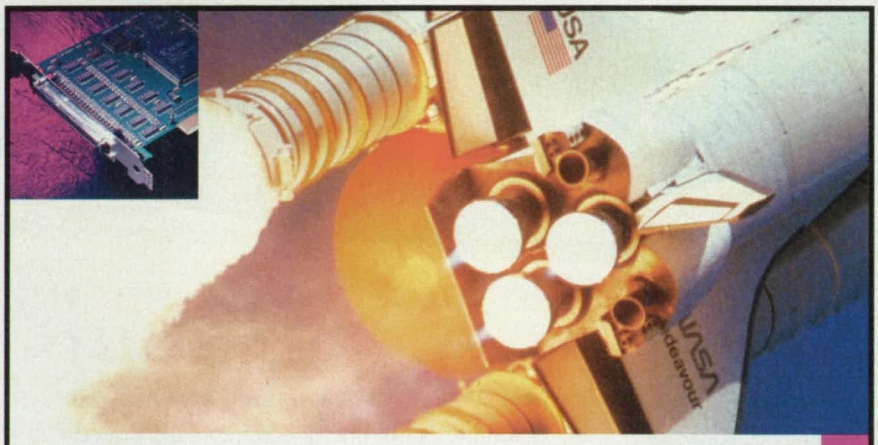

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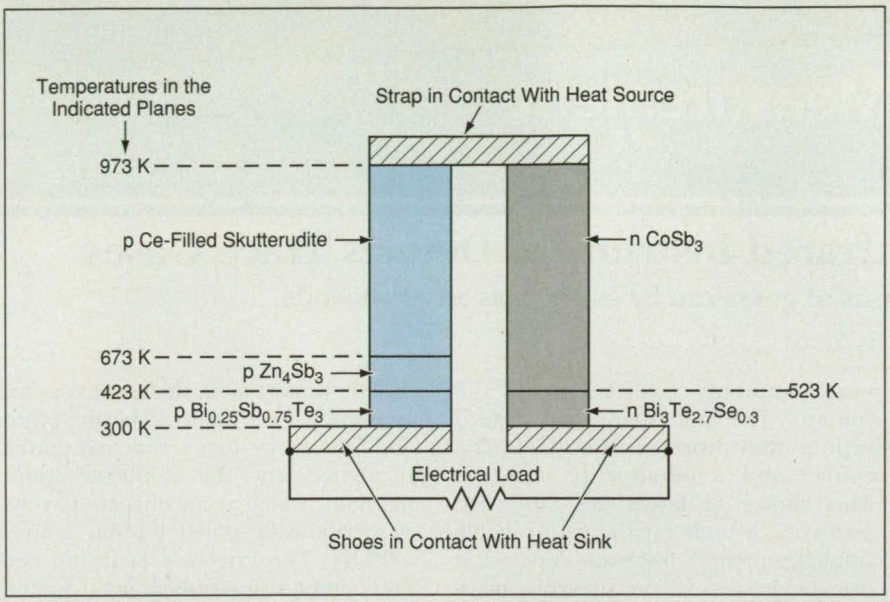
Highly Efficient Thermoelectric Unicouples

Thermal-to-electric conversion efficiencies as large as 15 percent have been predicted.

NASA's Jet Propulsion Laboratory, Pasadena, California

Advanced unicouples that contain carefully tailored combinations of thermoelectric materials are being investigated in an effort to develop thermoelectric power generators that would operate with relatively high energy-conversion efficiencies between heat-source temperatures of about 1,000 K and heat-sink temperatures of about 300 K. [A thermoelectric unicouple is a part of a thermoelectric generator; a unicouple comprises one electron-conduction (n-type) leg and one hole-conduction (p-type) leg thermally connected in parallel and electrically connected in series.] Thermoelectric generators have no moving parts, are reliable, can operate unattended in hostile environments,



An **Advanced Thermoelectric Unicouple** is made of high-performance p- and n-type materials, each positioned and dimensioned so that it is exposed to a temperature interval in which its thermoelectric performance is maximized. The relative lengths of the segments shown here to scale are chosen to obtain a predicted overall thermal-to-electrical energy-conversion efficiency of about 15 percent. Fabrication and testing of the predicted prototype unicouple is in progress.

and are environmentally benign; because of these characteristics, they are particularly attractive for extracting electric power from waste heat from such diverse sources as geothermal power plants, industrial heat-generating processes, and automobile exhausts.

To achieve high thermal-to-electric energy-conversion efficiencies, it is desirable to operate thermoelectric devices over large temperature gradients and to maximize the performances of the thermoelectric materials in the devices. However, no single thermoelectric material is suitable for maximizing the efficiency over the entire range between the contemplated source and sink temperatures. Therefore, the approach taken in designing the present advanced thermoelectric unicouples involves the use of different thermoelectric materials, each of which exhibits optimum performance in a different portion of the temperature range.

The figure schematically depicts a thermoelectric unicouple of the present type optimized for a source temperature of 973 K and a sink temperature of 300 K. This unicouple is made of high-performance thermoelectric materials, including (1) previously known state-of-the-art materials, (2) novel p-type alloys based on Zn_4Sb_3 and $CeFe_4Sb_{12}$, and (3) novel n-type alloys based on $CoSb_3$. Each of the p and n legs comprises segments of the various materials joined both thermally and electrically in series.

In general, the relative positions and lengths of the segments in each leg of a unicouple like this one must be chosen, taking account of the thermal conductivities of the materials, so that each segment is exposed to that portion of the source-to-sink temperature range for which the material of that segment exhibits its maximum thermoelectric performance. In addition, the ratio between the cross sections of the n and p legs must be chosen to optimize overall performance in the face of differences between the thermal and electrical conductivities in the two legs. To a first approximation (ignoring contact resistances and other relatively small effects), the energy-conversion efficiency of the unicouple depends on the ratios among the lengths of the segments but not on the overall length of the legs. However, the overall electrical and thermal resistances and the output electric power do depend on the overall length of the legs.

This work was done by Thierry Caillat, Alex Borshchevsky, Jeff Snyder, Jean-Pierre Fleurial, Andrew Zoltan, and Leslie Zoltan of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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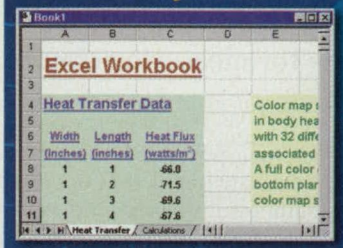

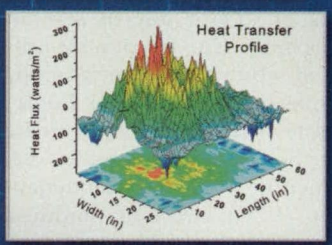

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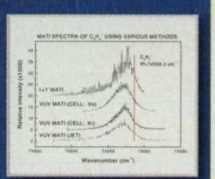
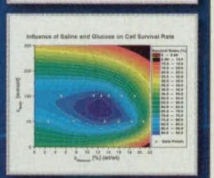
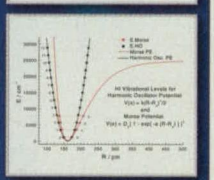
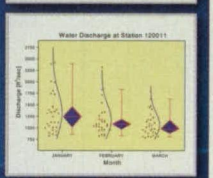
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Room-Temperature Infrared Instrument Detects Trace Gases

Times for measuring concentrations of gases can be as short as a few seconds.

Lyndon B. Johnson Space Center, Houston, Texas

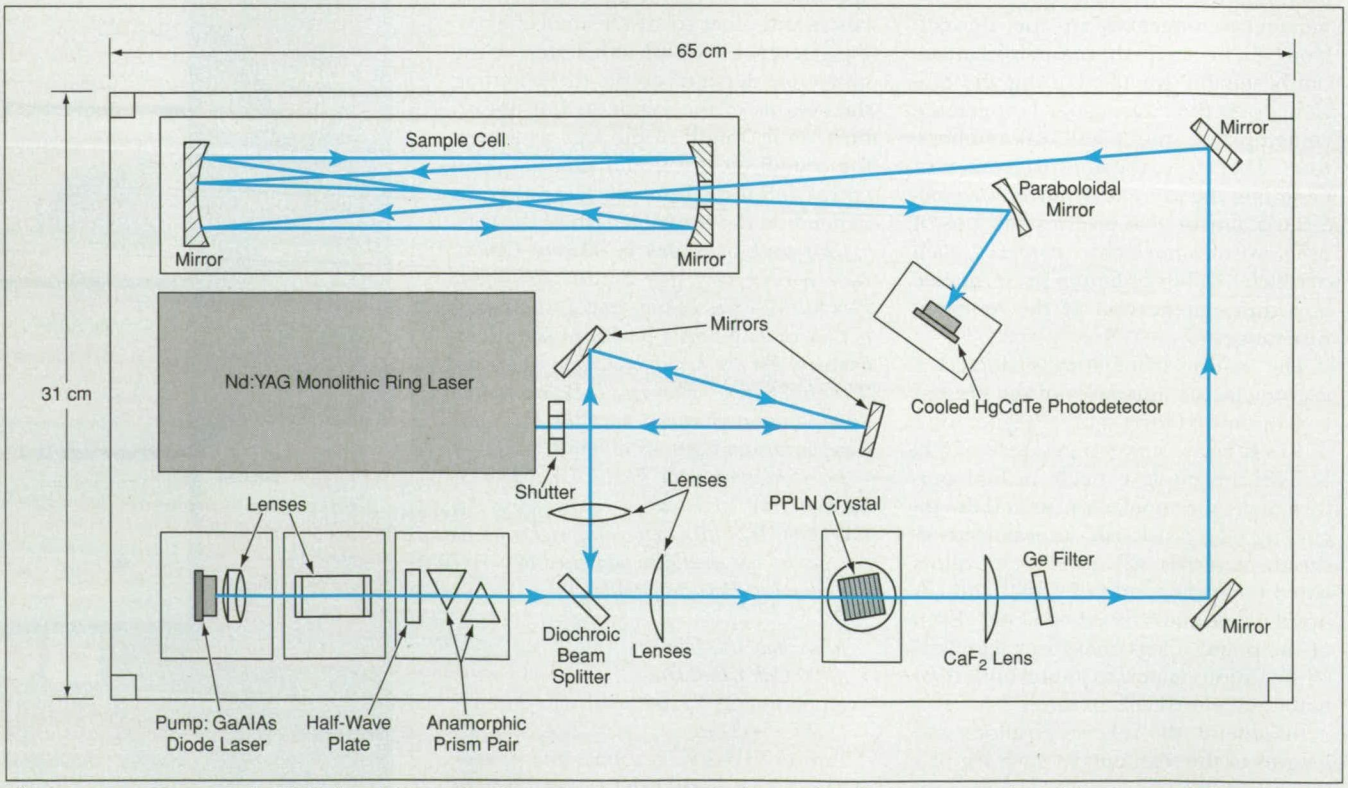
A compact, portable, mid-infrared, laser-based instrument that operates at room temperature has been developed for use in detecting trace concentrations of CO or any of several other gases in air. The instrument utilizes infrared absorption spectroscopy in a sample cell which either holds an air sample or is exposed to an airflow. The laser beam that interrogates the cell is formed by difference-frequency generation (DFG) in a bulk nonlinear optical medium excited by two laser beams.

The figure shows the optical layout of the instrument. One of the laser injection sources is a diode-pumped, nonplanar, monolithic ring neodymium: yttrium aluminum garnet (Nd:YAG) laser with 750-mW output power at a wavelength of 1,064 nm. In the terminology of nonlinear optics, it is the 'signal' laser. Another injection source is a 100-mW GaAlAs diode laser that operates at a wavelength of 865 nm, commonly referred to as the "pump." The laser diode is packaged with a thermistor, a thermoelectric cooler, and a monitor photodiode. This choice of lasers was motivated primarily by their capability of reliable single-frequency, low-noise operation over long times in the presence of vibration and of changes in temperature and humidity.

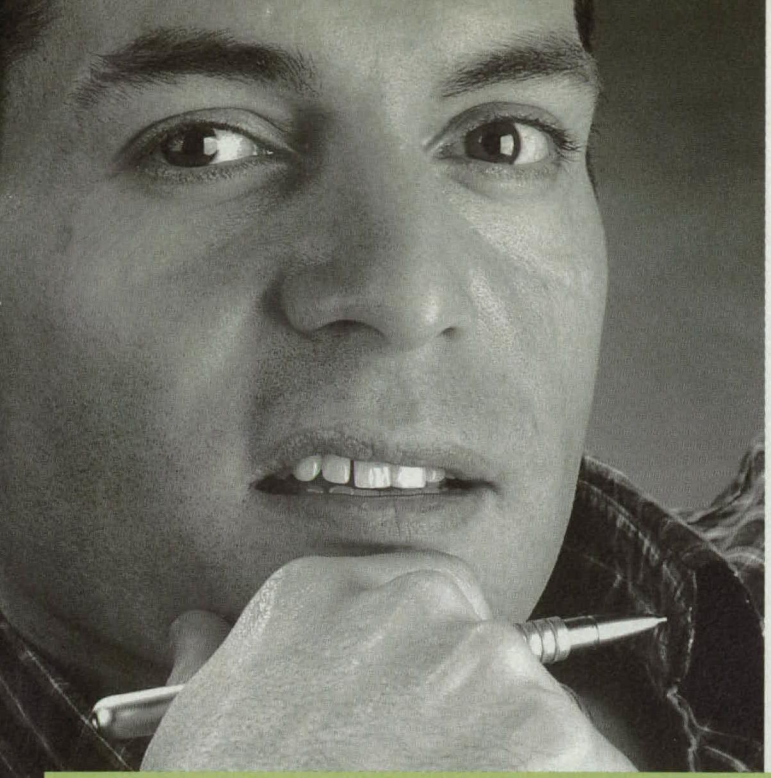
The output of the diode laser is collimated by a multielement lens. Both the diode laser and the lens are mounted on fixtures that ensure precise long-term alignment with minimum sensitivity to vibration. After collimation, the diode-laser beam (pumping beam) passes through a compact 40-dB isolator, then through a half-wave plate, then through an anamorphic prism pair, emerging as a vertically polarized beam that is nearly mode-matched to the signal laser beam for efficient DFG.

The pump and signal beams are combined by a dichroic beam splitter and focused by a lens, at nearly normal incidence, into the nonlinear optical medium, which is an uncoated crystal of periodically poled lithium niobate (PPLN). The crystal is *z*-cut and contains eight strips with domain grating periods ranging from 22.4 μm to 23.1 μm in 0.1-μm steps. For difference-frequency mixing to produce an idler beam at a wavelength of 4.6 μm, the optimum period was found to be 22.9 μm at room temperature. The idler beam is the one that is used to probe the sample cell.

The idler beam is collimated by an uncoated CaF_2 lens, then separated from the pump and signal beams by a germanium filter. The idler beam is then directed into the sample cell, which is a multipass cell aligned for 92 passes between mirrors separated by 20 cm to obtain an effective path length of



This **Instrument Measures the Mid-Infrared Absorption Spectrum** of a trace gas in the sample cell. The concentration of the trace gas is then computed from the measurement data.



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about 18 m. The multiple passes are used to increase the measured optical absorption by the trace gas of interest, so that the trace-gas-measurement signal can substantially exceed detector noise and optical interference. An off-axis parabolic mirror collects the idler beam at the output of the cell, and focuses it onto an HgCdTe photodetector maintained at a temperature of –65 °C by a three-stage Peltier cooler. In the output of the photodetector, absorption signals take the form of amplitude modulation. The output of the detector is digitized by a data-acquisition card that serves as an interface to a laptop computer. The card is also used to control a small mechanical shutter to block the signal beam for 10 seconds every three minutes for taking "dark" readings.

The spectroscopic information collected by the computer consists of the photodetector output voltage as a function the laser-frequency-control voltage (the signal used to control the current supplied to the diode laser and thereby control the pump wavelength). A time trace of the photodetector output voltage is a function of time averaged over 10 to 1,000 sweeps minus dark voltage. The time trace can be converted to a wavelength trace, once the pump frequency as a function of time is known. Depending on the number of sweeps used to generate the average, the spectrum can be updated at intervals that range from 1 to 20 seconds. At any point in the frequency scan, the concentration of the absorbing gas species of interest can be calculated by applying the Beer-Lambert law.

The entire instrument including power supplies and electronics is contained in an aluminum case that measures 31 by 31 by 65 cm. The instrument draws less than 50 W of electric power and can be operated from car batteries. The instrument has been shown to be capable of detecting CO in air at atmospheric pressure at mole fractions as low as 100 parts per billion, with a precision of 1 part per billion and an accuracy of 0.6 percent at an averaging time of 10 seconds. The use of a diode laser equipped with an external cavity could enable tuning over a wave-number range of 700 cm^{-1}, making it possible to detect several trace gases, including N_2O, CO_2, SO_2, H_2CO, and CH_4.

This work was done by Konstantin P. Petrov, Robert F. Curl, and Frank K. Tittel of Rice University for **Johnson Space Center.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Test and Measurement category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22864.

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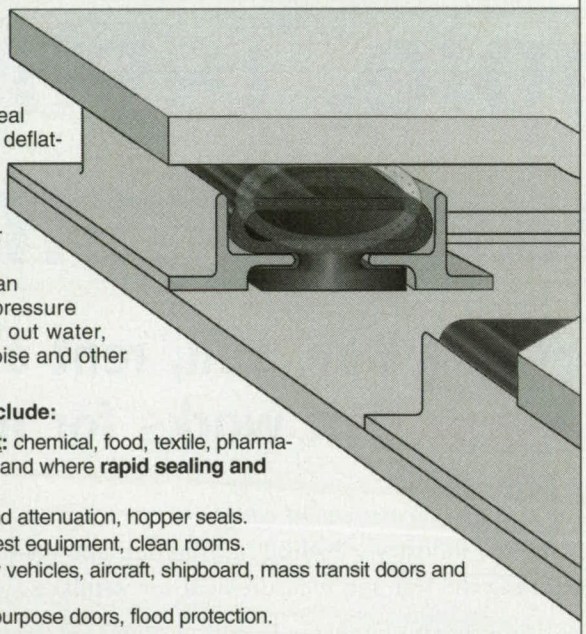

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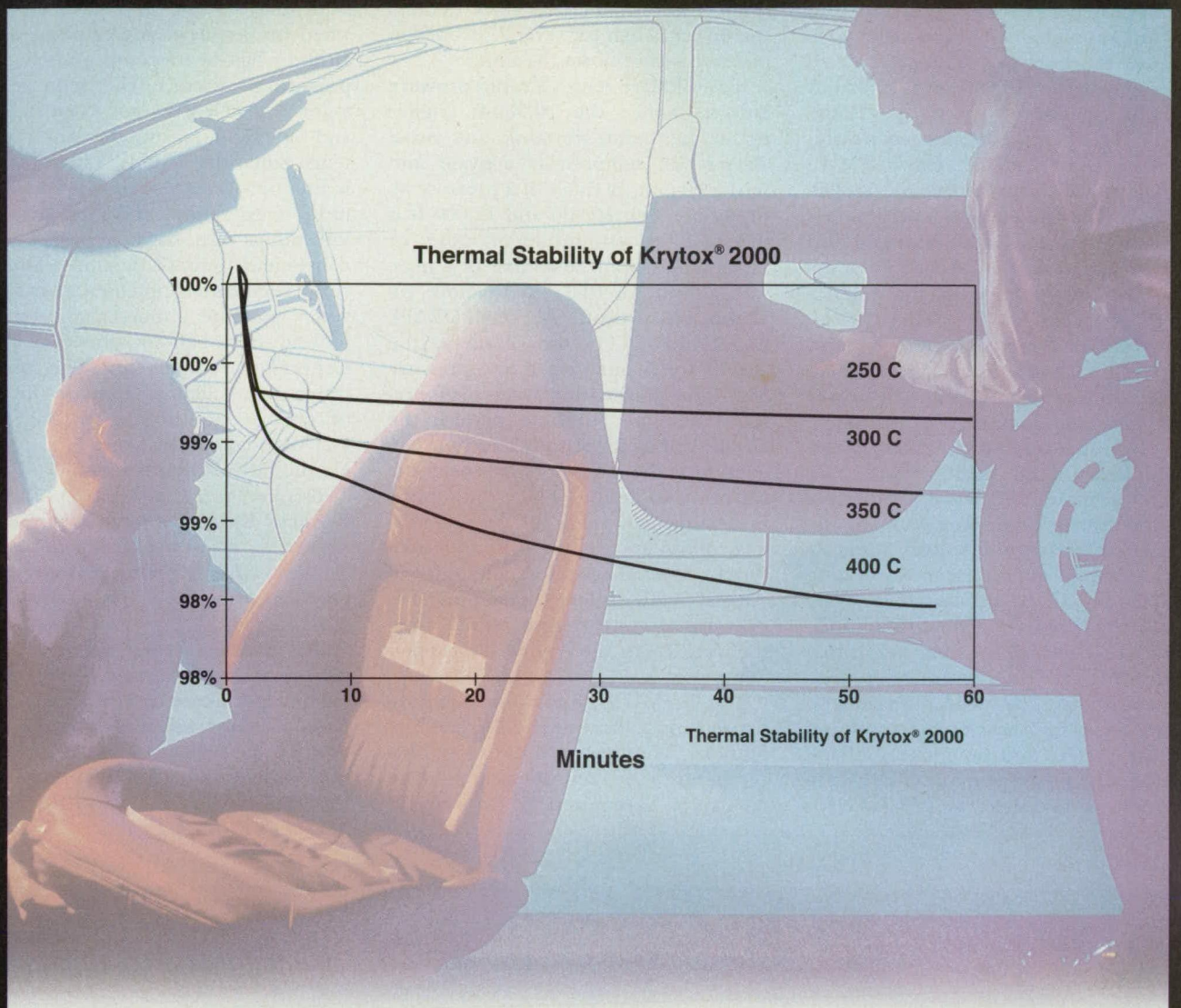
Personal Cabin Pressure Alarm

Aircraft crewmembers would be alerted to prevent hypoxia.

John F. Kennedy Space Center, Florida

Compact instruments, similar in appearance to common personal pagers, have been proposed for warning aircraft crewmembers that cabin air pressure has decreased to a potentially dangerous level. An instrument of this type, called a "personal cabin pressure monitor and warning system" (PCPMWS), implements a warning protocol consistent with Federal Aviation Administration (FAA) require-



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ments for commercial flight crews to (1) use supplemental oxygen after a 30-minute exposure to a cabin pressure altitude between 10,000 and 12,000 ft (about 3,050 and 3,660 m), or (2) immediately when the cabin pressure altitude exceeds 12,000 ft. The PCPMWS would provide both 10,000- and 12,000-ft warnings. The elapsed time between these two warning altitudes could also serve as an indication of the rate of decompression, and thus of the urgency of the situation.

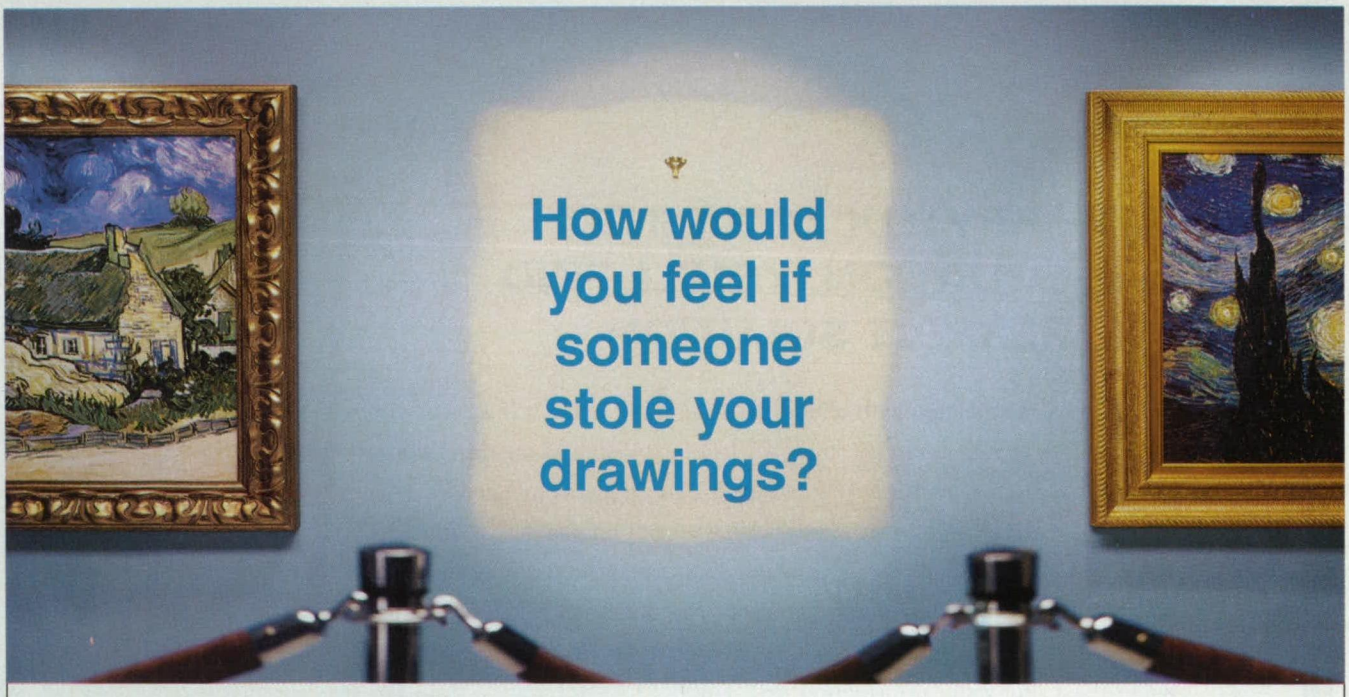
A PCPMWS is a state-of-the-art system which incorporates recent advances in sensors, low-power electronic circuitry, and high-density packaging of electronic circuitry. A production-model would be small, robust, and highly accurate. A PCPMWS contains a battery, an internal temperature-compensated pressure monitor, a microprocessor, an audio alarm, a vibrating alarm, and visual displays that would include a flashing light-emitting diode and a digital display or bar graph that would indicate the current cabin pressure altitude. The display would also serve as an indicator of the condition of the battery and functioning of the system when a momentary "TEST" button was pressed. Because a PCPMWS is a safety device, the user must depress the power switch for several seconds in order to power down the unit.

If a PCPMWS senses a cabin pressure altitude above the 10,000-ft trigger point, the audio, vibrating, and visual alarms will temporarily activate and start a 30-minute timer. If a pressure altitude between 10,000 and 12,000 ft is detected for 30 minutes or more, or immediately upon detection of a pressure altitude of 12,000 ft or more, all alarms will activate. A "TEMPORARY ALARM RESET" button will silence the alarms for 5 minutes. If the pressure condition causing the alarm is still present after the 5-minute period, the alarms will again sound. The user can configure the unit not to repeat the alarms, if so desired. Since the supplemental oxygen rules for general-aviation pilots are slightly different than for commercial operators, the unit will automatically select the applicable pressure altitude trigger points when the user selects the type of flight operation intended.

The PCPMWS is useful for both pressurized and nonpressurized aircraft operations. The device would serve as a reminder to the crew when supplemental oxygen is required for nonpressurized aircraft, and serve as a warning when the required safe cabin pressure altitude has been compromised in a pressurized aircraft. The main advantages of a PCPMWS are its portability and independence of other aircraft systems. Since the PCPMWS architecture is microprocessor-based, pressure altitude, temperature, and local pressure indications can be displayed in any convenient units of measure. Thus, it could serve as a supplemental or emergency pressure altimeter or pressure monitor for a balloon, glider, or other nonpressurized aircraft. The microprocessor could also calculate the rate of change of altitude, so that the PCPMWS could also serve as a supplemental rate-of-climb indicator.

This work was done by Jan A. Zysko of **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Test and Measurement category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-6373. Refer to KSC-12168.



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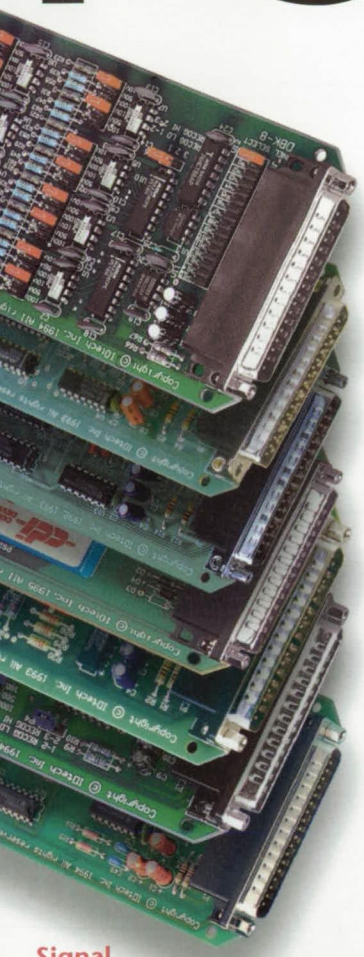

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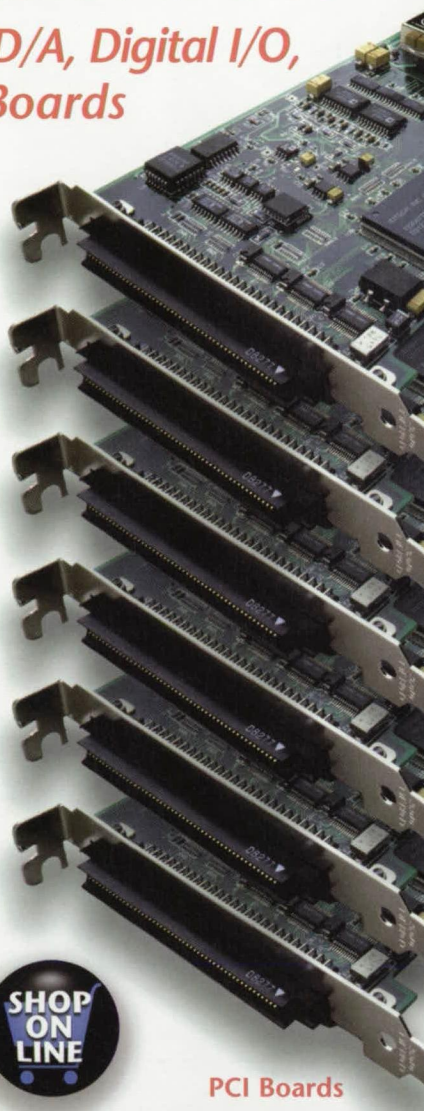

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Analog outputs (16 bit/100 kHz)	4	2	–	4	–	4
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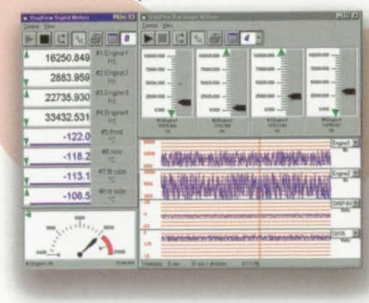

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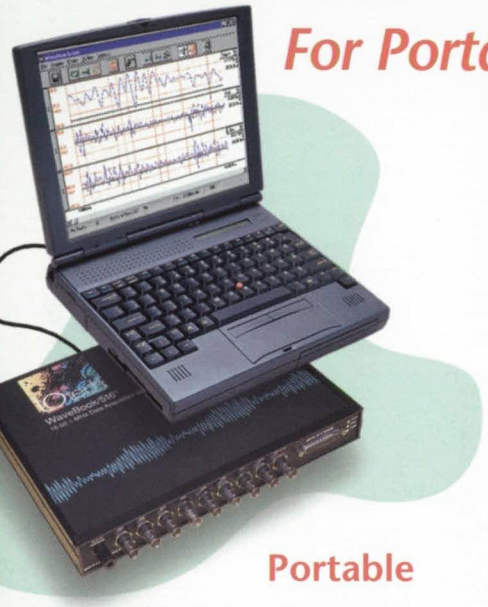

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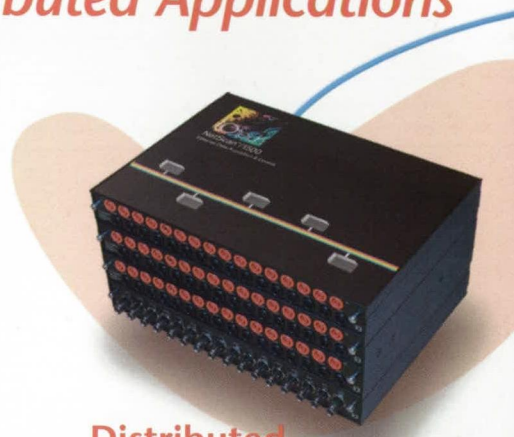

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October 2000

A Tale of Corrosion in Sealed Connector Bags ..... IIa
Microelectromechanical SPDT Switches 4a
Reactive-Ion Etching of Smooth Vertical Walls in Silicon 6a
Using Light to Fabricate Photonic Devices 7a
Making Submicron Features by Ion Etching through PMMA Masks 8a
Scanning Probe Position Encoder Yields Subnanometer Precision 9a
New Products 10a

Cover: True-Connector Corp.'s C-Series RF coaxial connectors. Photo courtesy True-Connector Corp.

A Tale of Corrosion in Sealed Connector Bags

Cristek's experience and subsequent analysis upon finding corrosion on connectors in sealed storage bags supports a change to a military specification.

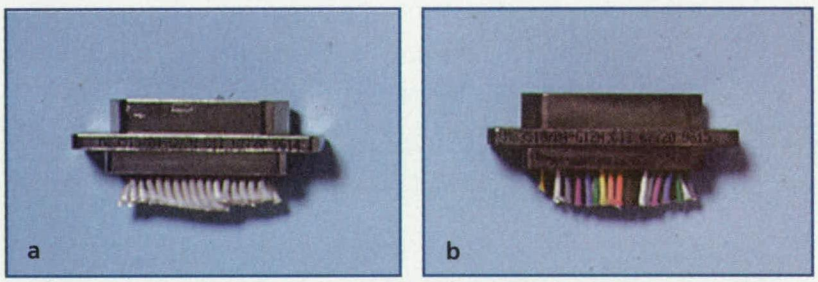
Those in the industry know that connector component suppliers at all levels follow prescribed procedures when manufacturing electrical connectors. These procedures affect molding, plating, epoxy formulation and curing, wire manufacture, assembly, testing, and packaging and storing. And for years the procedures served the industry without incident.

But in 1997 Cristek discovered sporadic cases of corrosion in M83513-style connectors. In these cases, the corrosion on the electrical connectors was found when the prewired connector assemblies were removed from factory-sealed bags. In all such cases, the corroded parts were terminated to wire per MIL-W-22759/33, the insulation being ethylene-tetrafluoroethylene (ETFE).

It is ironic that even with many controls and requirements this corrosion was caused by wire insulation which was compliant with all military specifications and passed all requirements. The usual reaction to corrosion found on a wire harness that has been in storage for a while would be to assume that the part was packaged or stored incorrectly, and that there was an isolated contamination problem. Historically, the solution has been to scrap the product without in-depth analysis.

When the problem was first reported to Cristek, more than 500 connector assemblies dating from 1994 to 1997 were inspected from finished-goods stock. Sporadic corrosion was found on some connectors, while others with the same date codes had no corrosion. The only factor shared by corroded and uncorroded connectors was the presence of M22759/33 wire.

Tests and analyses were conducted to try



Two electrical connectors with date codes 9614 (a) and 9615 (b). Both are nickel-plated aluminum shells with gold-plated copper contacts. Both were in original sealed bags until removed in 1997. Both were built with components with the same lot numbers. The only difference is that 9614 was built with M22759/11 wire and 9615 with /33 wire. Note that the shell on date code 9615 is visibly corroded while date code 9614's is not.

A closeup of the cross section of corrosion salts on a gold-plated nickel-underplated copper contact. The fluorine had attacked, reduced, and removed nickel from under the gold, creating a nickel-fluoride salt on the contact surface.

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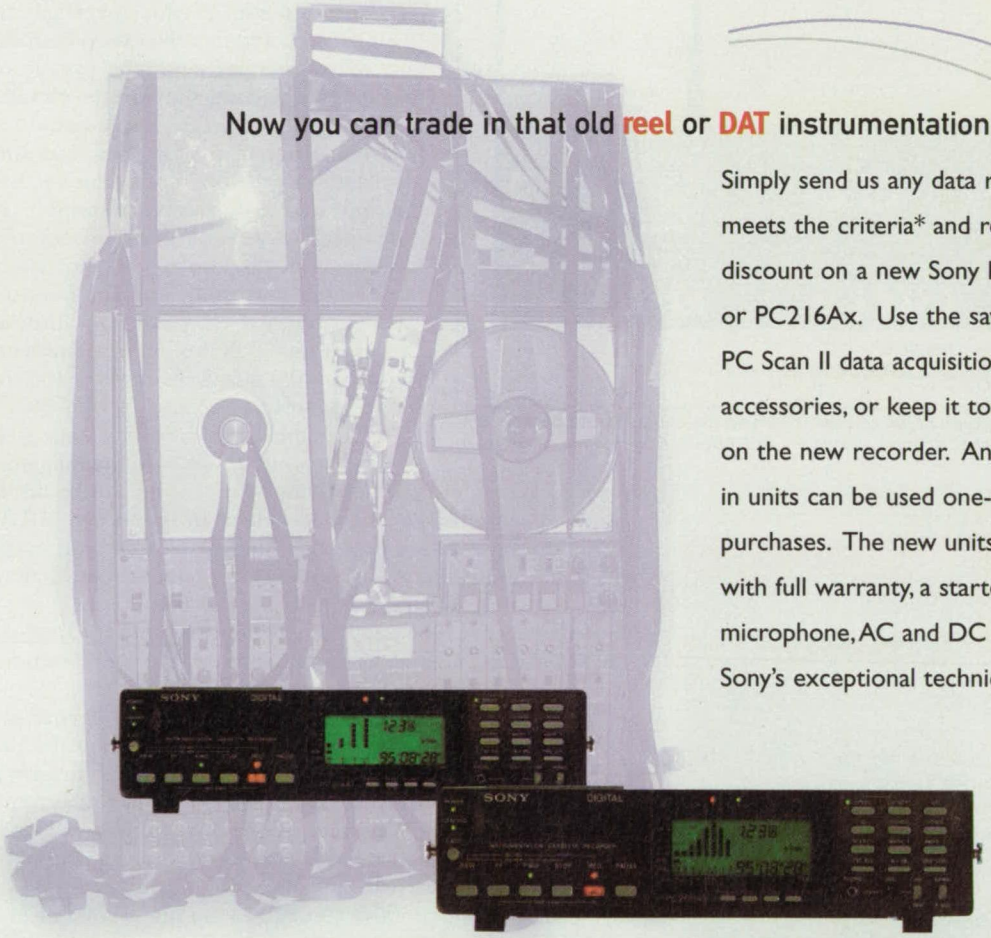

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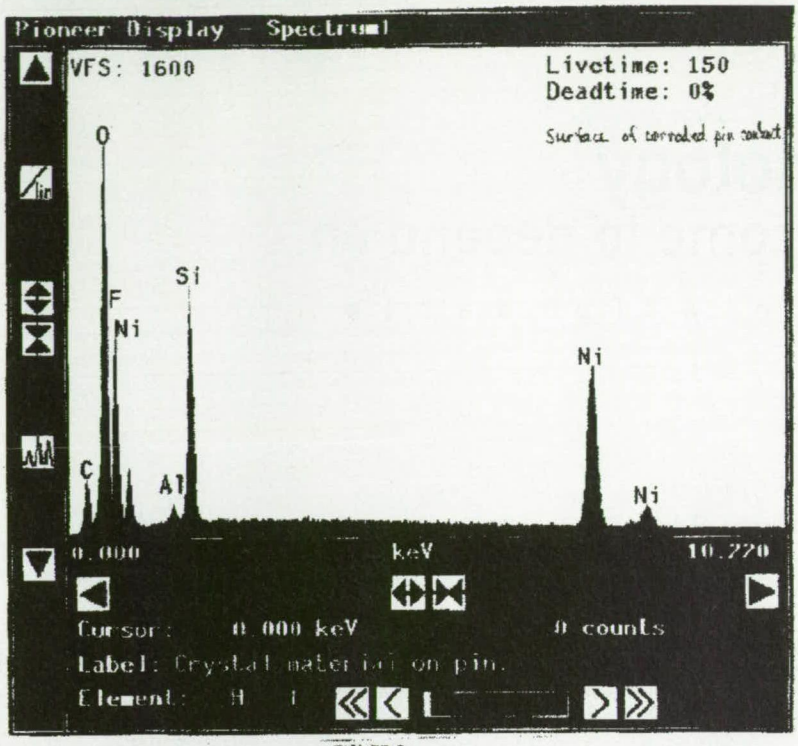

FIGURE 6
SEM/EDS GRAPH OF CORROSION ON CONTACT

Scanning electron microscopy (SEM) graph of the corrosion salts on the contact cross section. Elements present are carbon, oxygen, nickel, fluorine, aluminum, and silicon. Corrosion is assumed to be nickel fluoride.

to find the cause of the corrosion. Advanced research techniques, including ion chromatography, scanning electron microscopy (SEM), and Fourier transform infrared (FTIR) analysis, were applied to examine the wire insulation, the epoxy, the contacts and their plating, and finally the packaging bags.

The results indicated that the wire insulation was outgassing fluorine ions that attacked most of the exposed metals and plating on the connectors. Fluorine is a very corrosive element in certain forms—e.g., hydrofluoric acid—including simply as ions.

In the process of this investigation, Cristek discovered that the excess fluorides and other volatiles could be greatly reduced by subjecting the wire to elevated temperatures. Cristek implemented a bake-out program for all assemblies with insulated wire before packaging. At first this appeared to be a viable solution to the outgassing problem. It was discovered, however, that the process did not always prevent the corrosion, and the bake-out was discontinued early last year. Instead, Cristek disqualified the wire manufacturer whose wire was positively traced to the corrosion in most cases.

Unfortunately, this move does not guarantee that some other wire manufacturer will not change the "recipe" for its insulation and cause this or similar problems in the future. MIL-W-22759 does not define or restrict the volatiles that can outgas from wire insulation. Also, end users were not previously aware that this wire insulation outgases appreciable amounts of potentially reactive elements, such as fluoride, chloride, and sulfate. In fact the military aerospace industry has considered this wire to be "bullet-proof" for a number of years.

Although the ETFE wire meets the MIL-W-22759 specification, it may have excessive or nonpolymerized fluorides present that, when trapped in close proximity to metal surfaces as they were in the sealed poly bag, outgas at room temperatures. Highly corrosive fluorides, such as hydrofluoric acid, will attack metal surfaces and cause severe corrosion. It seems reasonable to expect that the wire specification should address this potential problem and impose limitations on the allowable outgassing.

In reality there is no quick, reliable, cost-effective test for corrosive outgassing of wire insulation. The end user has no control over this problem, and no guarantee that any lot of wire from any manufacturer will not outgas excessive corrosive elements. It is also unknown how much outgassing would cause problems like corrosion.

The optimum solution would be to change MIL-W-22759 to define and limit corrosive outgassing. Cristek supports this effort to publicize the problem with this wire by sharing information at symposia and technical meetings, by releasing a GIDEP industry alert, and by publishing articles in trade journals such as this one. Cristek also supports the request that the specification be changed.

For more information, contact the authors of this article, June Cabourne, senior project manager (714-618-2008; e-mail: june@cristek.com) or Cristi Cristich, president and CEO of Cristek Interconnects (714-618-2001; fax: 714-535-4897; e-mail: cristi@cristek.com); www.cristek.com.

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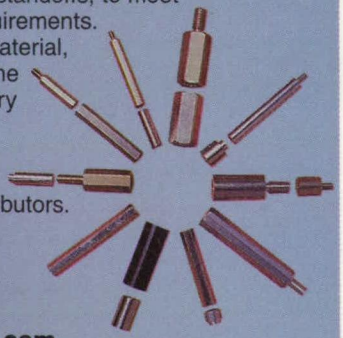

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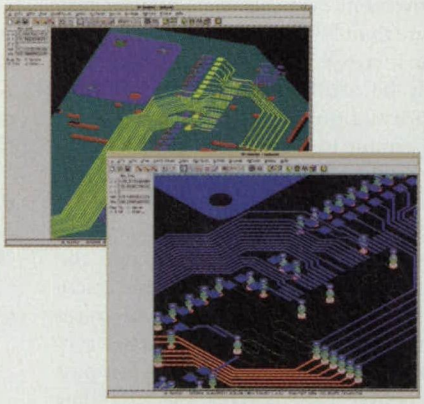

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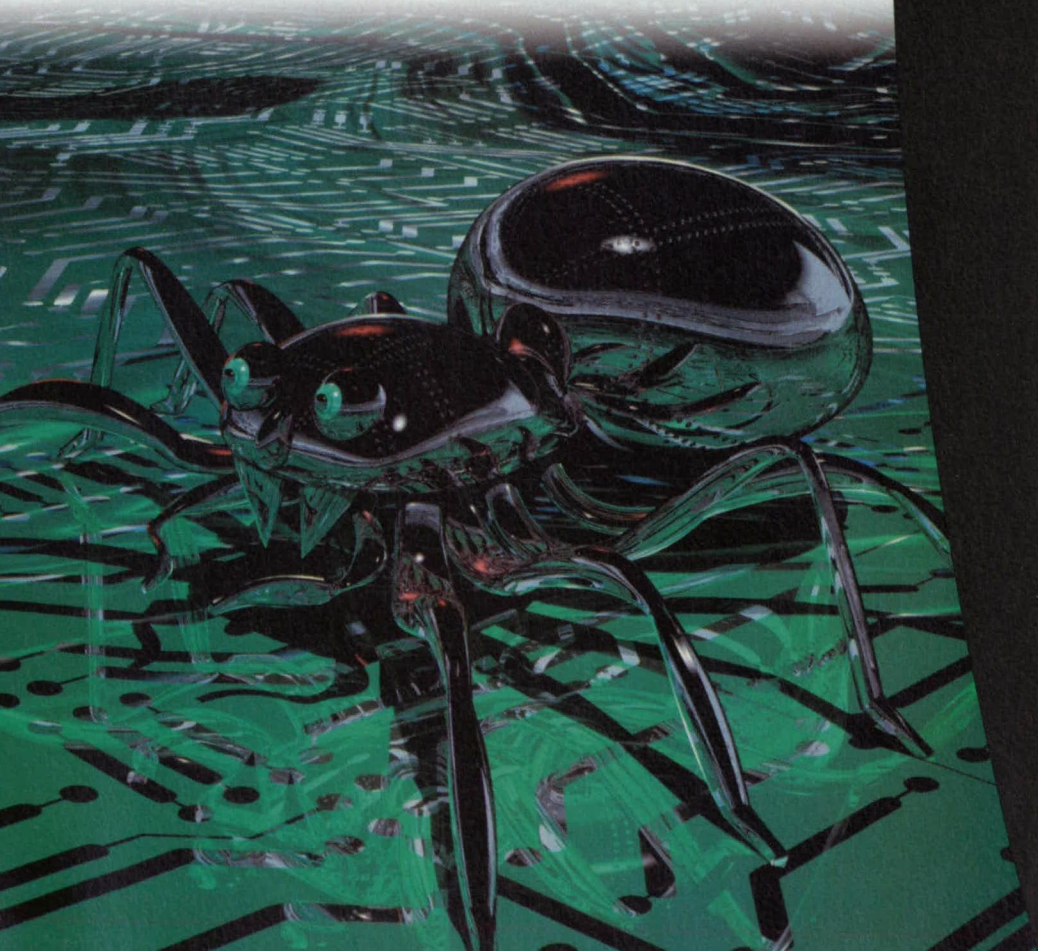

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Microelectromechanical SPDT Switches

With respect to isolation, insertion loss, and bandwidth, these would surpass other RF switches.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microelectromechanical single-pole, double-throw (SPDT) switches with predominantly planar configurations have been proposed for use in radio-frequency (RF) circuits. These switches would have overall dimensions of the order of a few millimeters and would be fabricated by micromachining techniques compatible with those used to fabricate microelectronic circuits; as such, these switches would be attractive for incorporation into inexpensive, highly integrated electronic circuits. Moreover, because of their fundamentally electromechanical character and in contradistinction to semiconductor switches, these switches are expected to exhibit minimal intermodulation distortion and very low power dissipation.

The simplest switch of this type (see Figure 1) would be an assembly of (1) a T junction between an input signal path and two output signal paths and (2) two electrostatically actuated microscopic reed contacts — one on each output path — close to the junction. In a normal operational condition, one reed contact would be closed ("on") and the other open ("off"). In this condition, the switch would provide an excellent dc and low-frequency block between the input line and the "off" output line, and an excellent conductive path between the input line and the "on" output line. However, as determined in a computational simulation, the isolation between the input line and the "off" output line at a frequency of 30 GHz would be only about 28 dB — a level that is considered mediocre in the industry.

The placement of a second reed contact directly after the first on the output lines would improve the isolation, but only by about 15 dB across most of the band from dc to the maximum design frequency (e.g., 30 GHz). A much more significant increase can be obtained by placing that second contact at a quarter wavelength of 30 GHz; this would yield an improvement over the single contact case of more than 30 dB across the entire band.

The increase in isolation at 30 GHz can clearly be attributed to the impedance transformation of the second-contact open circuit to a short directly after the first contact. However, the high isolation across the rest of the band is the result of the unique circuit created by the topology. At frequencies between dc and the maximum design frequency, the open-circuited contacts and section of transmission line between them act as two very small capacitors in series with a low-pass filter between them. This low pass filter characteristic provides the high isolation at the intermediate frequencies.

Following similar reasoning, one could increase the isolation further by placing a third set of contacts at a quarter wavelength from the second contact (see Figure 2). Yet rather than placing the third contact at a quarter wavelength of the maximum fundamental frequency, if one desires to suppress second harmonic leakage, both the second and third contacts can be placed at a quarter wavelength of the second harmonic frequency to achieve an ultra-broadband, low-loss SPDT switch. This can be done with minimal effect on the performance at the fundamental frequency. For the dc-to-30-GHz case, computer simulations reveal 84 dB isolation at 30 GHz and 68 dB at 60 GHz; insertion loss at 30 GHz is predicted to be about 0.5 dB. This level of performance would exceed any other known RF SPDT switch.

This work was done by Sam Valas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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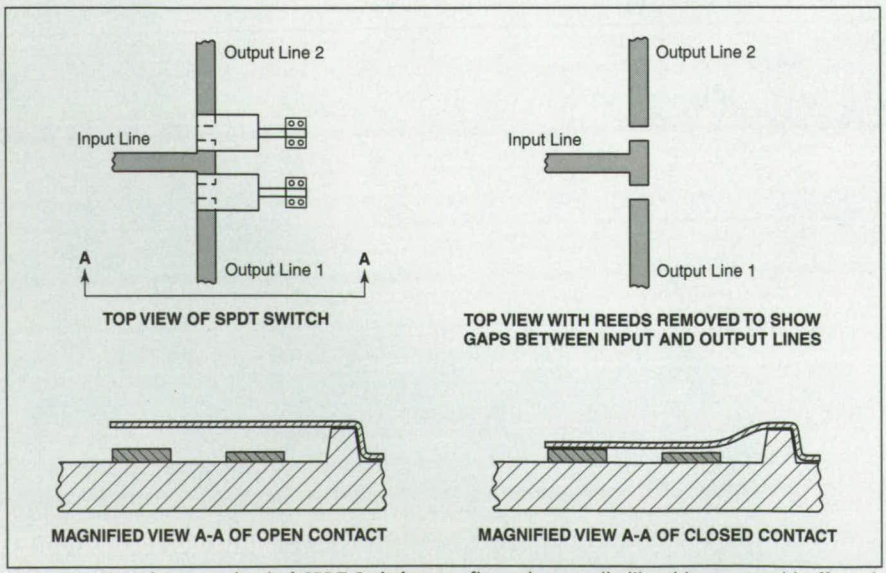

Figure 1. **Microelectromechanical SPDT Switches** configured generally like this one would offer advantages over semiconductor switches.

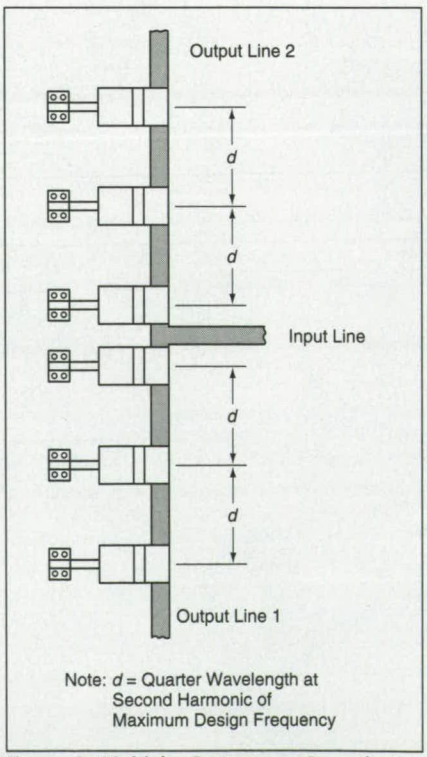

Figure 2. **Multiple Contacts at Properly Designed Intervals** would provide superior isolation between the input line and the "off"-side output line.

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For More Information Circle No. 473

Reactive-Ion Etching of Smooth Vertical Walls in Silicon

These walls are suitable for low-loss optical waveguides.

NASA's Jet Propulsion Laboratory, Pasadena, California

etb MATERIALS

An advanced technique of deep reactive-ion etching (DRIE) has been developed for fabricating smooth vertical walls in silicon wafers. These walls are suitable for use as bounding surfaces of optical waveguides in photonic and optoelectronic devices. The roughness of a typical 8-μm-high vertical wall surface of a waveguide made by this technique is <20 nm; by keeping the roughness at such a low level, one helps to ensure that the waveguide is capable of low-loss optical transmission.

The specific DRIE technique, denoted the "Bosch" technique, involves repeated exposure of a photoresist-masked silicon wafer to (1) an etchant (SF_6 + C_4F_8) plasma in alternation with a passivant (C_4F_8) plasma. To ensure vertical, smooth walls, it is necessary to investigate, in detail, the effects of variations in all photoresist and DRIE process parameters and then to exert tight control over these parameters. Among other things, this means that the photoresist process parameters must be chosen to obtain perpendicular photoresist side walls. The power levels of the plasma apparatus in the etching and passivating steps, the durations of these steps, the total number of etching-and-passivating cycles, and the pressures and rates of flow of the SF_6 and C_4F_8 gases must also be investigated in detail and then controlled to obtain vertical walls with low roughness.

Ranges of parameters that have been investigated in a DRIE apparatus at NASA's Jet Propulsion Laboratory are the following:

- Total process time — 10 to 30 minutes;
- Pressure — 5 to 40 millitorr (0.7 to 5 Pa)
- Durations of etching and passivating steps — 4 to 10 seconds;
- Rate of flow of SF_6 gas during etching step — 100 to 180 standard cubic centimeters per minute (sccm);
- Rate of flow of C_4F_8 gas during etching step — 30 to 70 sccm;
- Platen power during etching step — 12 to 16 W;
- Coil power during etching step — 575 to 650 W;
- Rate of flow of C_4F_8 during passivating step — 90 to 140 sccm;
- Platen power during passivating step — 0 to 2 W;
- Coil power during passivating step — 575 to 650 W.

This work was done by Chi Wu, Stephen Vargo, and Tasha Turner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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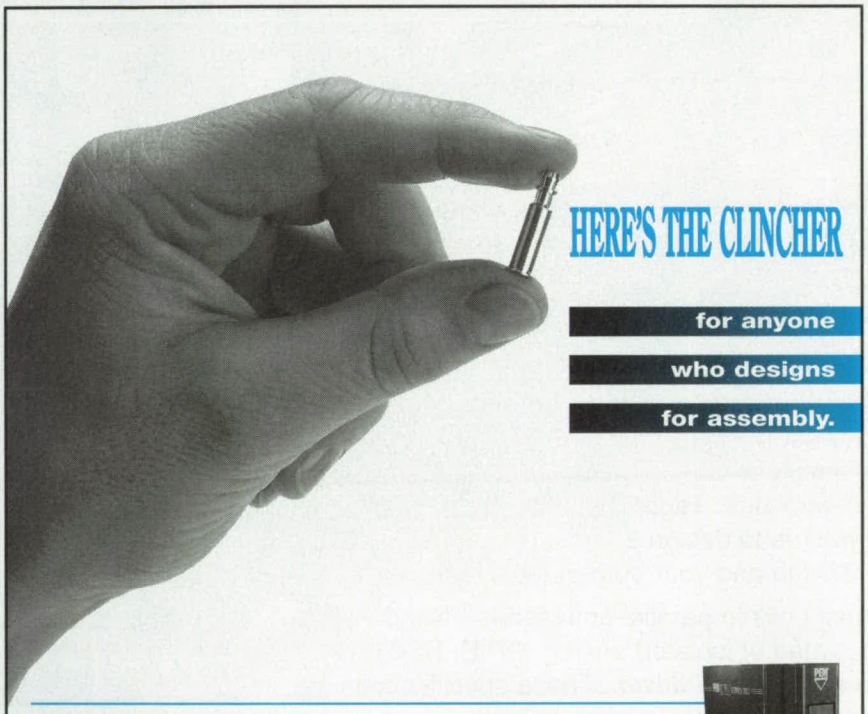

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For More Information Circle No. 486

Using Light To Fabricate Photonic Devices

Pondermotive forces from patterned laser beams are used to arrange micron-sized particles.

Marshall Space Flight Center, Alabama

A developmental apparatus and process for the fabrication of photonic devices utilize intense, focused laser light projected and/or diffracted in controlled patterns. The apparatus and process can be used in a microgravitational environment to form microscopic three-dimensional device structures (e.g., filters or other periodic structures with characteristic dimensions of the order of a wavelength of light). The apparatus and process could also be used on Earth to fabricate devices with two-dimensional structures.

The apparatus is designed to generate and control the pondermotive effects of intense laser light on molecules and other small particles. These effects include radiation pressure and optical trapping forces, and are accompanied by secondary effects like dipole/dipole interactions. The process exploits these effects in order to arrange large numbers of such particles in patterns that correspond to the microscopic photonic-device structures that one seeks to fabricate.

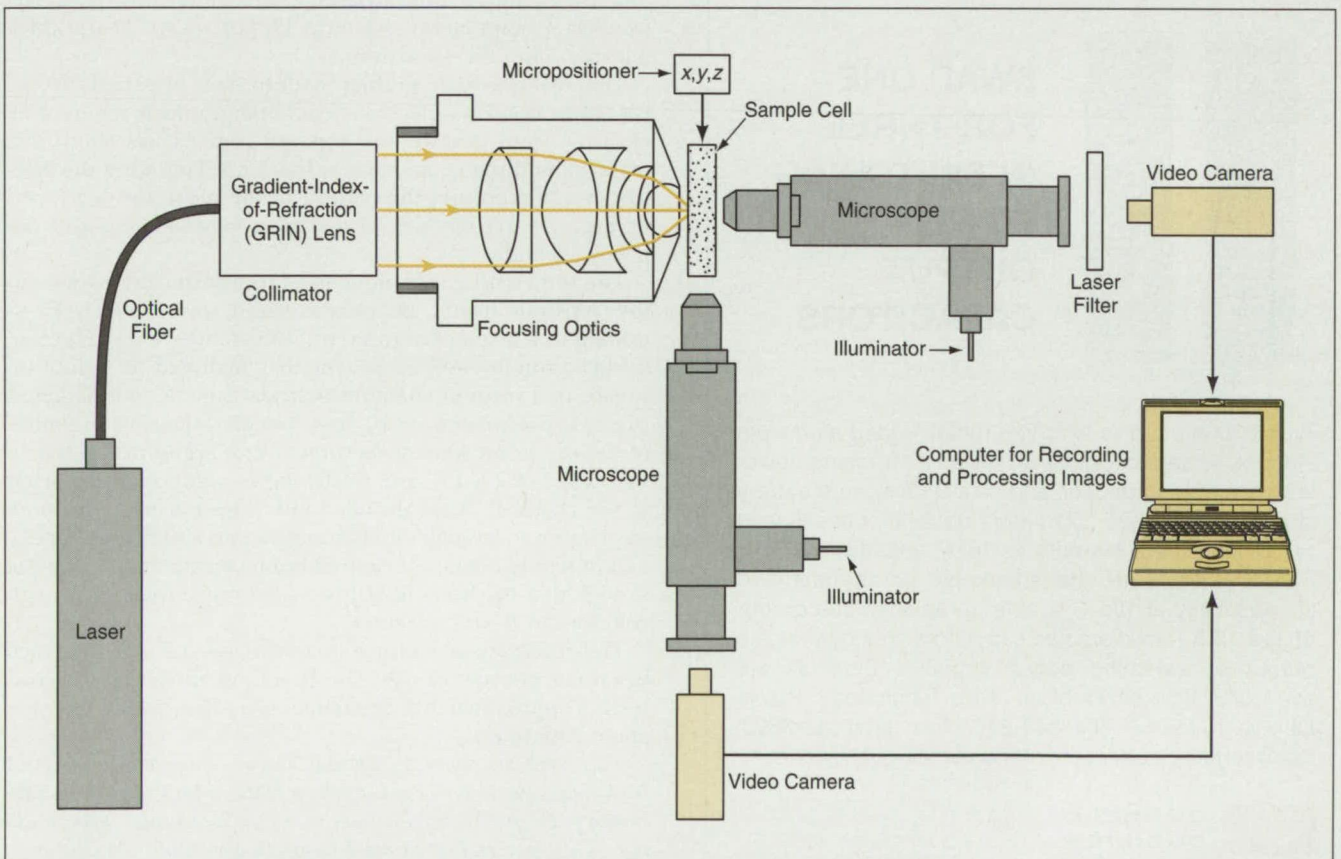
The apparatus (see figure) includes a compact laser that generates a high-power-density beam, plus optics for either focusing the beam to a spot of adjustable size or else forming the beam into a desired pattern. The apparatus also includes a sample cell wherein the device is to be formed, external equipment (not shown in the figure) that provides controlled flows of depositional and fixative gases to the sample cell, microscopes fitted with video cameras for monitoring what happens in the sample cell, and three-dimensional (x,y,z) translation stages for the sample cell and for the optical components.

If, for example, a device is to be deposited on a glass plate, then the process begins with the preparation of a sample cell made from that plate (which becomes the rear plate of the cell) plus a second plate. The rear plate can be treated to enhance the adhesion of particles that are to be deposited on it. The two plates are separated by a small gap and sealed together at their edges to form the cell. A suspension of particles (typically with sizes of the order of 1 μm) is prepared and put into the cell. The laser is focused into the cell from the front side (in a gravitational field, this must be the top side). The pondermotive effects (plus gravitation, if any) push the particles onto the rear plate and arrange them in the desired pattern.

The process is not yet well defined. Preliminary experimental data have shown that crystallization in two-dimensional patterns can be achieved by controlling particle patterns as described above, but motion of the suspending fluid tends to disrupt the crystallization. Future development efforts would have to address this issue, plus the issue of fixation to make the processed material more stable.

This work was done by Laurence Malley and Sergei Krivoshlykov of ALTAIR Center, LLC, for **Marshall Space Flight Center**. *For further information, contact the company at altairctr@aol.com.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; (256) 544-0021. Refer to MFS-31360.



An **Intense Patterned Laser Beam** is made to pass through the sample cell, wherein microscopic particles are suspended in a fluid. The pondermotive forces exerted by the laser beam on the particles arrange the particles in patterns corresponding to that of the beam.

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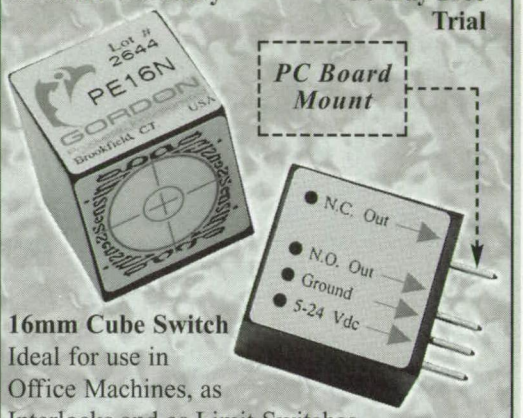

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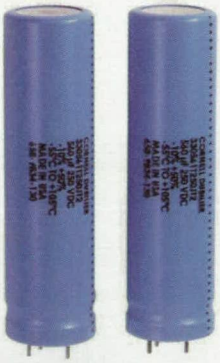

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Making Submicron Features by Ion Etching Through PMMA Masks

etb FABRICATION

The proper choice of materials and process parameters is critical to success.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that a substrate can be patterned with submicron features by the following procedure:

1. Coat the substrate with a layer of poly(methyl methacrylate) [PMMA], which will serve as an electron-beam resist to be patterned into an etch mask.
2. Pattern the PMMA by electron-beam lithography.
3. Ion-etch through the PMMA to transfer the pattern to the substrate.

The procedure has been used to fabricate a 600-nm-pitch diffraction grating; it could also be used to form submicron features on semiconductor and other devices.

Prior to the development of this procedure, it was known that submicron features can be produced in a PMMA resist by exposing it to an electron beam, then developing it. However, the transfer of submicron features from a PMMA mask to a substrate by either dry or wet etching had not been demonstrated. As a result of the development of the present procedure, it is now known that success in the transfer of submicron features depends on the proper choice of the substrate material(s), the thicknesses of the substrate and PMMA, the etching method, and the etching conditions.

The substrate for the 600-nm-pitch grating was a 100-nm-thick gold film on a 5-nm-thick chromium layer on a quartz disk; the Cr and Au films were deposited on the disk in an electron-beam evaporation system. A PMMA resist 120 nm thick was spun onto the Au surface.

The 600-nm-pitch grating pattern was imparted to the PMMA by use of an electron-beam lithography machine. The electron-beam dose in the exposed regions was about 200 $\mu C/cm^2$, and the beam current was 5 nA. Following the electron-beam exposure, the pattern in the resist was developed by use of a 1:3 mixture of methyl isobutyl ketone and isopropyl alcohol.

The ion etching technique used to transfer the pattern to the substrate could be characterized, more precisely, as milling by a beam of argon ions. The etching was performed in an argon-ion-milling system that included an ion-beam source in a vacuum chamber that was capable of evacuation to a base pressure of 4×10^{-8} torr (≈5 μPa). During operation of the ion-beam source, the pressure of argon in the system was raised to 2×10^{-4} torr (≈0.03 Pa) by addition of argon gas to the chamber at a controlled rate. This operating pressure was chosen to be high enough to generate a sufficient population of ions to obtain the desired beam current density, but not so high that the beam would be excessively dispersed through collisions with gas molecules.

The ion-beam-generating potential was 1.5 kV. The total beam current was 10 mA. The beam was spread over a cross section approximately 5 cm in diameter. The etching time was about 2 minutes.

This work was done by Thomas George, Richard Muller, Paul Maker, and David Barsic of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

NPO-20649

Scanning Probe Position Encoder Yields Subnanometer Precision

etb TEST & MEASUREMENT

A novel device measures position in real time.

NanoWave Inc., Billerica, Massachusetts

In today's manufacturing world, the need for ultraprecise position measurement and control grows as feature sizes shrink in the semiconductor industry and the world of microelectromechanical systems (MEMS) impinges on conventional manufacturing. Now NanoWave, a start-up company with roots at MIT, has announced that its subnanometer precision measurement technology is ready for licensing and commercialization.

The NanoWave scanning probe position encoder (SPPE) will enable manufacturing equipment to move and be controlled in real time at subnanometer or atomic levels of precision, with the capability of reliable measurement over 12 inches of travel — a key requirement for the semiconductor industry as it moves to 300-mm wafer fabrication.

The SPPE comprises four primary components: the head unit with oscillating scanning probe microscopy (SPM) probe; the holographic grating or reference scale with a highly periodic signal structure; the active gap-distance control system; and the signal processing unit, which measures position in real time, reliably and precisely, with NanoWave's patented phase-tracking system.

The sensor probe is oscillated with a sub-quarter-micron amplitude at a constant high frequency above the patterned holographic grating, which has an extremely small grating period (100-278 nm). The probe senses the field generated between its edge and the grating surface. This is amplified by a sensor amplifier. Meanwhile the SPM probe oscillation is detected by an independent sensor from which the reference signal is synthesized. This output is mixed with the SPM output, converting the position information into a phase-modulated signal referenced by the synthesized signal.

The numerical phase-tracking detection method provides digital interpolation simultaneously and yet allows an accurate phase accumulation as the grating scale moves in the X direction. Thus highly repeatable and superfine-resolution position encoding becomes possible in an ordinary atmospheric environment.

A line-patterned holographic grating is used for applications requiring measurement and control in the X and Z axes. A dot-patterned grating is used for applications requiring measurement and control in X, Y, and Z directions (Figure 1). When multiple probes are placed above such gratings, one can measure the motion in up to six axes with an atomic level of precision in each axis (Figure 2).

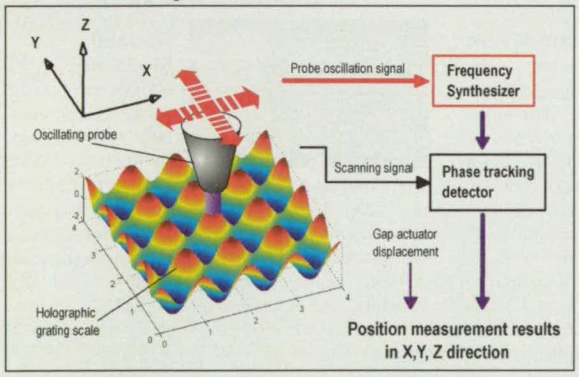

Figure 1. **Schematic** of the three-axis configuration of the NanoWave scanning probe positioning encoder.

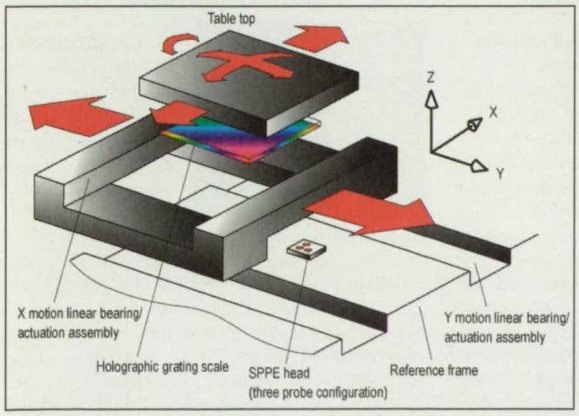

Figure 2. **One application** of the multiprobe SPPE in controlling movement of a laboratory table.

Among applications foreseen are semiconductor chip positioning at 50-nm rule, optical and DVD disk mastering, diamond turning of aspherics, and microelectromechanical systems (MEMS).

This work was done by Dr. Tetsuo Ohara, president and CEO of **NanoWave Inc.** *For further information about licensing and commercialization of this technology, contact Renee Buck at NanoWave, 20 Bankside Dr., Billerica, MA 01821; (978) 663-NANO (6266); fax: (978) 663-9941; e-mail: info@nanowave.com; www.nanowave.com.*

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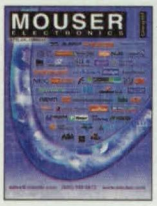

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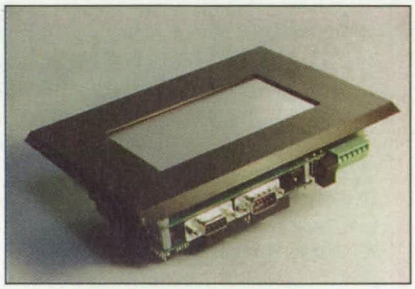
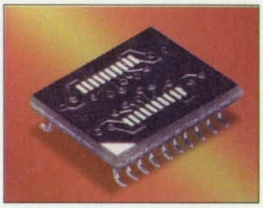


Touchscreen Embedded Controller

Mosaic Industries, Newark, CA, offers the SmarTouch Controller™, a C-programmable embedded computer with a built-in graphical user interface. The controller provides real-time control of dozens of analog and digital I/O lines, and combines a high-contrast 128 × 240 pixel display and a 5 × 4 touchscreen. It commands eight 12-bit analog input channels, eight 8-bit analog inputs, eight 8-bit D/A lines, 24 digital I/O, 4 high-current drivers, and two RS 232/485 ports. Precoded I/O drivers facilitate data acquisition, pulse width modulation, motor control, frequency measurement, data analysis, analog control, PID control, and communications.

For More Information Circle No. 750



Adapters for SSOP Devices

Aries Electronics, Frenchtown, NJ, introduces its line of Correct-A-Chip® adapters which allow new SSOP devices to be used on boards designed for the older-technology SOWIC packages without board rework or redesign. The SOWIC-to-SSOP adapters are available in a 20-pin version with other pin counts available in the near future (14-, 16-, and 24-pin). The adapters have an operating temperature range of –55 °C to 125 °C. Pins are hardened brass alloy with tin-lead plating.

For More Information Circle No. 751

Micropower Operational Amplifiers

The MCP6XX family of four 2.5-V micropower operational amplifiers from Microchip Technology, Chandler, AZ, features a supply current of 25 microamperes maximum with a single supply operation over the 2.5 - to 5.5-V range and a low bias current of one picoampere. The amplifiers offer offset voltage of less than 250 µV and are available in single (model MCP606), dual (model MCP608), quad (model MCP609), and single with a chip-select capability (model MCP607). All devices are fully specified from –40° to 85 °C with power supplies from 2.5 V to 5.5 V.

For More Information Circle No. 752

Process Display

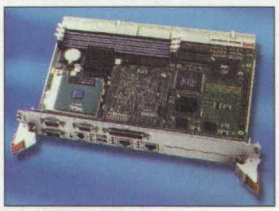
The D5600 process display series from DigiTec, Lancaster, PA, complements level, position, pressure, temperature, or thickness transducers. It comes in a 2" high or 4"high red LED with a 5 - or 7 - digit resolution. Operating from 95 to 265 VAC at 45 to 400 Hz, the unit features 2 SPST relay outputs and RS422 communication output, which is a continuous output at 1200 baud, ASCII format. The D5600 has two SPST relay outputs and an RS422 communication output standard, and an optional four-pushbutton programming box.

For More Information Circle No. 753

Embedded Vision Engines

Imaging Technology, Bedford, MA, offers the NetSight™ embedded vision engines, giving OEMs a choice of development environments — from an operating system based on Microsoft® Windows CE or Windows NT to a range of machine vision software tools and applications, including ITI's MVTools™, MVTools CE, SMART Search™, and Sherlock™. The unit is designed for use in automated semiconductor and electronics manufacturing equipment, such as robotic wafer sorter/handlers, cluster tools, wafer probes, and back-end IC manufacturing equipment.

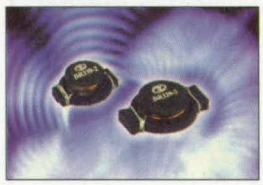
For More Information Circle No. 754



CompactPCI CPU

The CP603 model Mobile Pentium III® - based 6U CompactPCI CPU, from PEP Modular Computers, Pittsburgh, PA, utilizes a Pentium III processor in a 370-pin flip-chip pin grid array package. Operating at a clock speed of up to 850 MHz, the board features a 64-bit CompactPCI interface, which permits data transfer rates of up to 264 Mbytes/sec. The CPU offers a high-definition AGP/VGA graphics controller with 4 Mbytes of video RAM, two Fast Ethernet interfaces, one Ultrawide SCSI interface, and a slot for PMC mezzanine modules with 3.3-V capability.

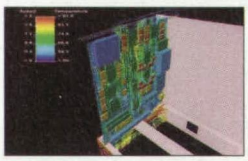
For More Information Circle No. 755



Surface Mount Inductor

Datatronics Romoland, Romoland, CA, introduces the DR339-X Series Inductors for DC-DC converter and switching power supply applications. With an inductance range from 0.47 to 100 µH and a rated current from 19.0 to 0.47 A, the inductor series is applicable for use in computers, telecommunications, medical devices, and instrumentation. The DCR value is 0.0097 to 1.1090 ohms, and the series offers height profiles as small as 0.197" and overall footprint profiles from 0.347" × 0.237". Custom inductance valves are available on request.

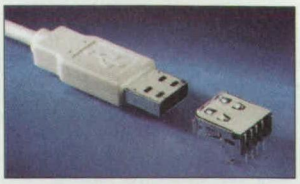
For More Information Circle No. 756



Thermal Modeling Software

Flomerics, Southborough, MA, releases the FLO/EDA, a new Web-based software product for the rapid creation of thermal models of printed circuit boards. FLO/EDA reads Intermediate Data Format data files, a format supported by all major electronic design automation software vendors, including Cadence, Mentor Graphics, and Zuken-Redac. The IDF file contains details of the board shape (including any cutouts or unusual shapes) as well as component size and placement. FLO/EDA matches each component against a central database and adds the required thermal information.

For More Information Circle No. 757



USB Connectors

Ranoda Electronics, Sunnyvale, CA, announces its line of Universal Serial Bus (USB) connectors, configured per the "A" version of the standard. It offers four in-line pins of brass or phosphor bronze, plated with nickel and finished with a gold flash. Two pins are intended for power, and two for signals over twisted pairs. The connectors feature a bandwidth of 12 Mbits/sec or better. Ranoda says this performance level supports connectivity among high-performance personal computers, Internet service providers, and high-speed data storage units.

For More Information Circle No. 758

High-Precision Gauges

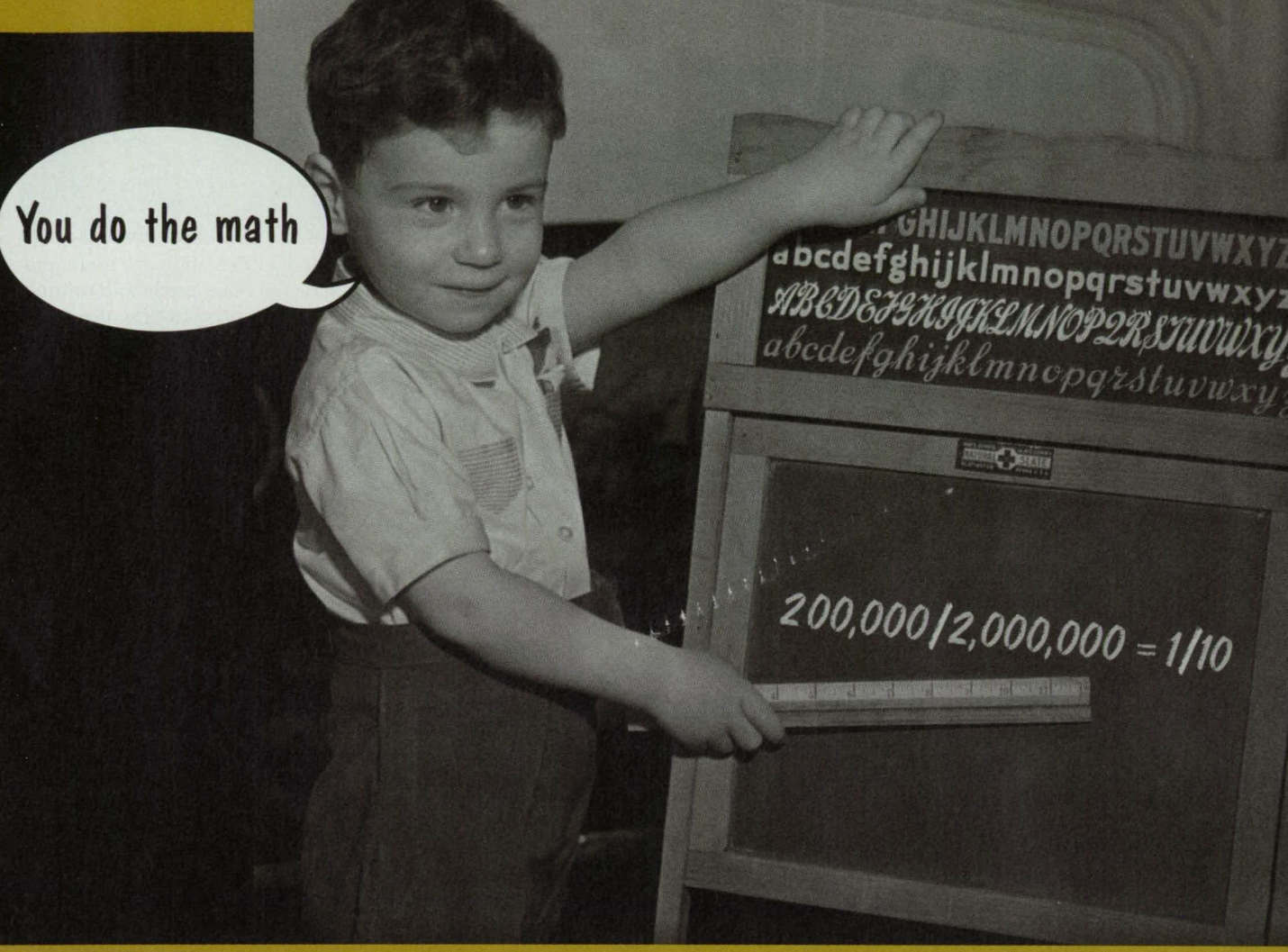
The 9530-NT UltraGage® and 9505-NT UltraGage™ from ADE Corp., Westwood, MA, measure 8,700 data points in less than 60 seconds. The company says this number of data points provides the high precision required for measuring thickness and shape and calculating stress. The 9505-NT UltraGage characterizes thin-film stress and wafer shape for patterned and monitor wafers. It correlates with x-ray diffraction, the only direct measure of thin-film stress. The 9530-NT applies ADE-industry standard metrology to back-grind, etch, and lap processes that reduce wafer thickness to as little as 150 µ.

For More Information Circle No. 759

Air Conditioners

The Pro-Ozone air conditioners from Rittal Corp., Springfield, OH, are offered in two performance classes — 8000 BTU or 10,000 BTU, cooling heat loads in the middle and upper levels of the spectrum. All units are available with the same dimensions (59" H × 15.75" W × 11.4" D), offering users varying cooling capacities with a common mounting cutout. The internal air cycle design contains increased distance (max. 1200 mm) of air intake and outlet. Standard rated operating voltages are 230 V and 115 V single phase 50/60 Hz, and 400 V and 460 V 3-phase 50/60 Hz.

For More Information Circle No. 760



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For More Information Circle No. 554

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Software Predicts Noise From Rotor-Wake/Stator Interactions

V072 is a computer program that predicts the noise generated by the interaction between the rotor-blade wake (fan wake) and the stator vanes of a turbofan engine. The program is a combination of subroutines from prior NASA programs, with many added features.

Limits on aircraft noise near airports are becoming more stringent. Noise associated with fans is a significant portion of the noise that emanates from modern turbofan engines. In order to reduce noise from fan stages, engineers rely on accurate computer programs to predict noise from new blading and duct designs. V072 is useful because it quickly predicts inlet and aft sound-pressure and power levels.

In V072, the computation of noise is divided into two parts: a rotor-wake calculation and the stator-noise-response calculation. First, V072 uses a semiempirical mathematical model of a wake to calculate the characteristics of the rotor wake at the leading edge of the stator. The fan stage is modeled as a constant-area annulus with the rotor blades and stator vanes represented as twisted flat plates. Empirical rotor-wake profiles are superimposed on a two-dimensional, analytically calculated mean flow. The wake model can be augmented by simple tip- and hub-vortex models. Wake harmonic magnitudes and amplitudes are then calculated at the leading edge of the stator.

The results from the wake-model calculation are then automatically fed as input to an analytical noise-prediction routine. More specifically, the unsteady flow predicted in the wake-model calculation is used to calculate the total harmonic power levels propagating upstream and downstream in the engine duct. The noise-prediction routine calculates inlet and aft sound-pressure and power levels for the blade-passage-frequency tones and their harmonics, along with complex radial mode amplitudes. The code can calculate the noise from either a fan-wake/outlet-guide-vane interaction or a fan-wake/core-stator interaction.

Although V072 is based partly on many simplifying assumptions about the fan geometry and the flow through the fan stage, V072 is nevertheless a useful software tool for designing to minimize fan noise. (The simplifications incorporated in the code make it unsuitable for analyzing cases that involve transonic or supersonic fan-tip speeds.) This program runs quickly on modern Unix workstations, making it possible to predict noise for many new designs in a timely manner, and thereby reducing the number of experiments needed to prove noise-reduction concepts.

This program was written by David Topol and Douglas C. Mathews of United Technologies for **Glenn Research Center**. *For further information on this code, please visit the following web site: http://www.grc.nasa.gov/WWW/5900/5940.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17065.

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Software for Obtaining Ideal SAR Chirps

A computer program introduces a predistortion into the chirp signal used to frequency-modulate a synthetic-aperture-radar (SAR) signal at the transmitter. The predistortion is intended to compensate for distortions introduced by nonideal performance of the various pieces of SAR equipment — especially the transmitter. More specifically, the predistortion is intended to make the signal in the receiver an ideal SAR signal in that it exhibits optimum correlation performance. The program is run as a calibration routine. It is used in conjunction with a closed calibration loop that includes the SAR transmitter and receiver, plus an arbitrary-waveform generator (AWG), which generates the predistorted chirp under computer control. The program causes the AWG to adjust the predistorted chirp iteratively until the chirp in the receiver differs from an optimum or reference chirp by less than a prescribed small measure of error. In a test in which a bad elliptical filter was used to simulate (with respect to distortion) the transmitting and receiving equipment of an SAR system, the program succeeded in generating a simulated receiver chirp within less than 1 dB of optimum.

This program was written by Andrew Berkun of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20420.

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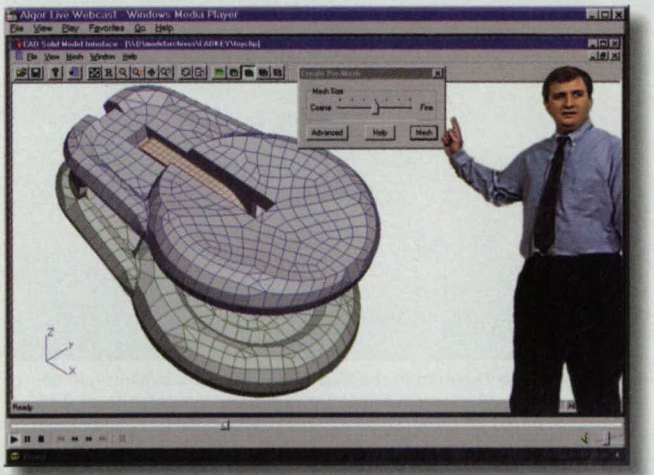
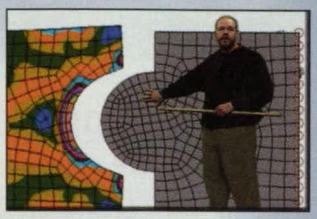


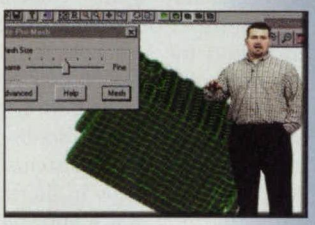
Algor's interactive software demonstrations range in topics from "What You Need to Know About FEA" to "Motion and Impact Using Algor's Mechanical Event Simulation vs. Motion Load Transfer" to illustrate how Algor software meets your engineering needs.

What You See is What You Get

The images shown here were extracted from actual webcast footage. The TV quality you see here is the same quality you will see on your desktop computer screen if you have a T1, DSL or cable modem connection, or you may request a webcast on CD-ROM.

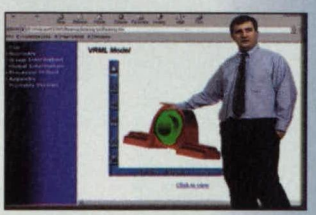


See our industry-leading Mechanical Event Simulation technology with linear or non-linear materials. In the webcast shown above, the von Mises material was used on a model which experiences impact.



Find out about FEA within CAD for solid modelers such as SolidWorks shown here.

Watch our engineers do FEA modeling in Algor, including the capability to build models like this composite wing.



See how you'll get started with Algor's FEA design, analysis and visualization capabilities with built-in HTML report support shown above.

See how you'll do linear static stress with composite elements, as in this model of a wing.

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Interlocking Wing-Leading-Edge Thermal-Protection Tiles

These tiles are shaped to prevent damage at inter-tile gaps.

Ames Research Center, Moffett Field, California

Insulating tiles with interlocking shaped gaps have been developed for use in protecting the leading edges of the wings of aerospacecraft against excessive heating during hypersonic flight (including reentry into the atmosphere). Other thermal-protection systems have been studied for this application, including those based on active transpiration cooling and heat-sink concepts. These systems have been described extensively in literature during the past thirty years and recently have been proposed for use on two hypersonic vehicles: the National Aerospace Plane (NASP) and the Slender Hypervelocity Aerothermodynamic Research Probe (SHARP). However, because these systems are very heavy and are expensive (millions of dollars) to fabricate and to install, the probability of using these systems in the near term on the surfaces of commercially operated reusable launch vehicles is low.

Currently, the leading-edge surfaces on such vehicles as the space shuttle orbiter and X-34 reusable launch vehicle use reinforced carbon/carbon and/or ceramic tiles with a straight gap configuration. In straight-gap tile systems, it is

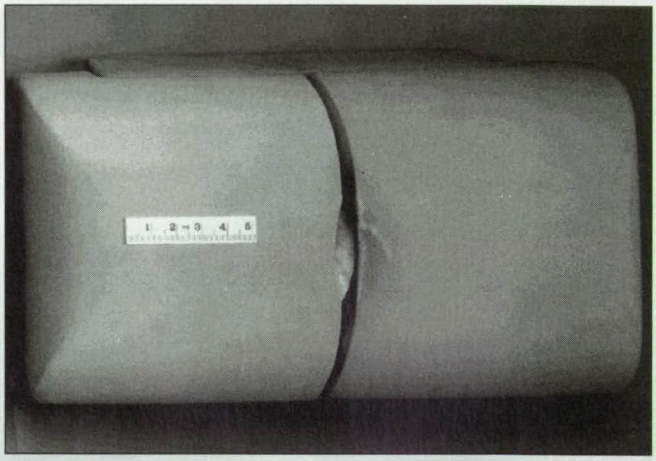

Figure 1. **Damage Occurred in the Gap** of a model of a straight-gap pair of tiles without filler that was subjected to a surface temperature of 2,300 °F (1,260 °C) in an arc-jet flow.

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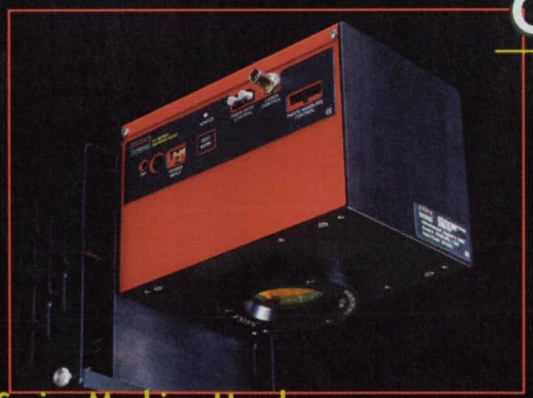

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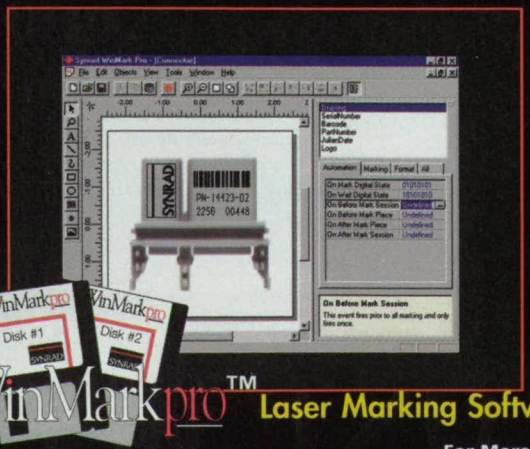

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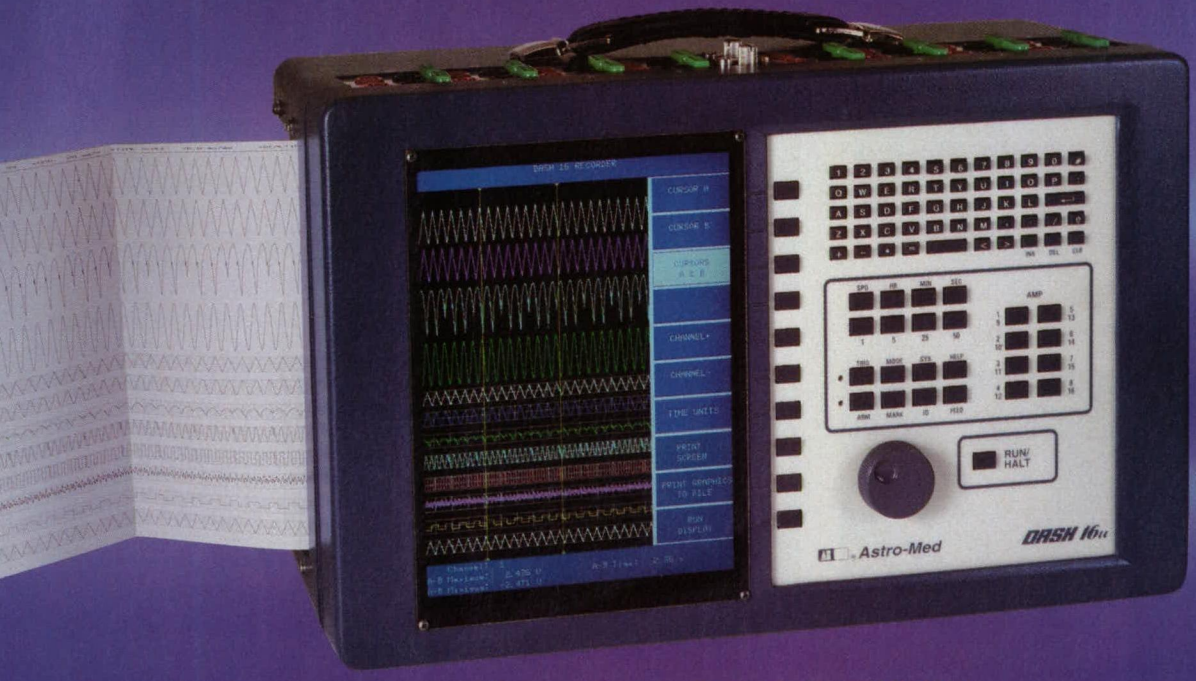

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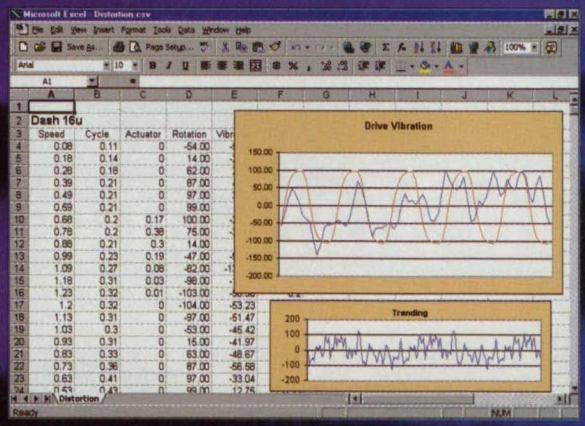

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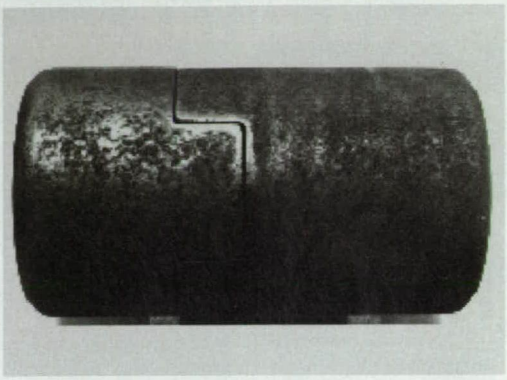
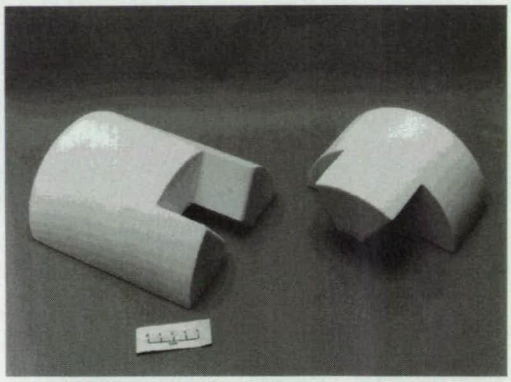
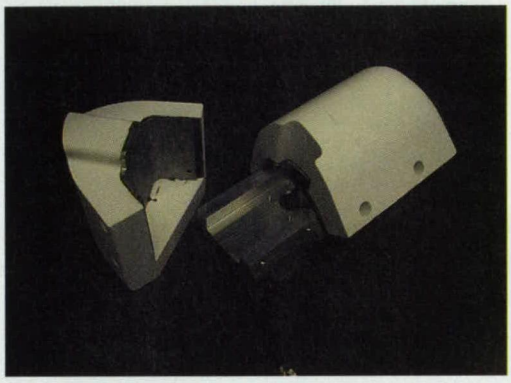


Assembled Interlocking Tiles



Disassembled Interlocking Tiles (Wedge Design)



Disassembled Interlocking Tiles (Modular Design)

Assembled Interlocking Tiles (Modular Design) During Successful Test in Arc Jet at Surface Temperature Near 2,400 °F

Figure 2. **Interlocking Tiles**, when properly shaped, are less vulnerable to damage in the gaps than are straight-gap tiles.

necessary to use gap fillers to prevent hot boundary-layer gases from flowing through the gaps and creating what is known as nozzle flow. Because of the limitations of the materials available for making gap fillers, the straight gap configuration is restricted to temperatures no more than about 2,000 °F (≈1,090 °C). Without a gap filler, the high-energy boundary-layer gases that are generated along a stagnation streamline (leading edge) during entry into the atmosphere would cause major damage to adjoining tiles and would cause overheating of the structure underlying the tiles. Figure 1 shows an example of damage in the gap of a model of a straight-gap pair of tiles without filler.

The interlocking-tile concept (see Figure 2) was proposed to prevent damage in the gaps between tiles. A suitable interlock configuration divides a gap into regions of subsonic and supersonic flow regimes. The flow in the portion of the gap in the area of the stagnation streamline is subsonic. The flows in the portions of the gap in the outer portions of the tile (these portions are called bleed gaps) are in the supersonic regime of the affected leading-edge component. This concept substantially reduces the temperatures down the side wall of the gap by reducing the pressure drop through the gap below a value that can generate nozzle flow. Two patented configurations of this type, called wedge and modular, have been proposed for protecting the leading edges of wings on commercial aerospace vehicles. Tiles of these configurations have withstood arc-jet-flow tests at surface temperatures above 2,800 °F (greater than about 1,540 °C), without incurring damage in their gaps.

This work was done by David A. Stewart of **Ames Research Center.**

This invention has been patented by NASA (U.S. Patent No. 5,772,154). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14031.

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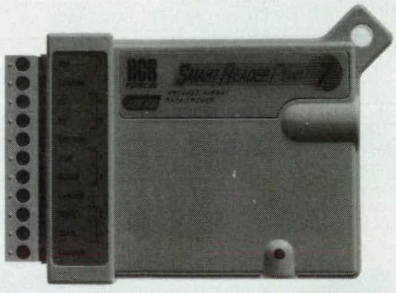

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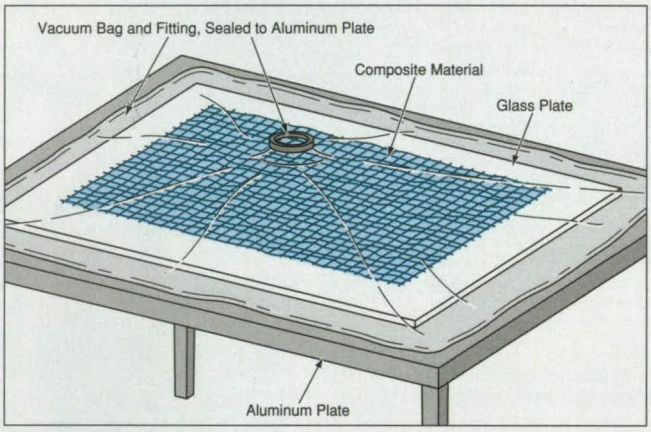
Glass Cure Plates for Fabricating Flat Composite Panels

Costs are lower than those of aluminum cure plates.

Goddard Space Flight Center, Greenbelt, Maryland

Glass plates are used as cure plates in a modified process for the fabrication of flat composite-material (matrix/fiber) panels. In the unmodified previous version of the process the cure plates were made of aluminum.

A cure plate provides a smooth, flat surface on which a polymer resin and reinforcing carbon fibers are laid up. The layup is then vacuum-bagged on the cure plate, and the polymer is cured by heating the entire assembly in an autoclave.



The Glass Plate provides the smooth surface needed to form a composite-material panel.

To be useful as cure plates, aluminum plates must be machined and polished to the required flatness and smoothness. Both the cost of material and the cost of finishing are considerable. In addition, because aluminum is soft, it is easily scratched; hence, when an aluminum cure plate is used repeatedly, costly resurfacing is necessary to maintain an acceptable cure surface.

In the modified process, an aluminum plate is used as a substrate for curing, but no attempt is made to maintain its surface finish. Instead, a glass plate is simply laid on the aluminum plate, so that the glass surface becomes the cure surface. The glass plate should be at least 1/4 in. (6.4 mm) thick, and the glass should be of a tempered or heat-resistant type.

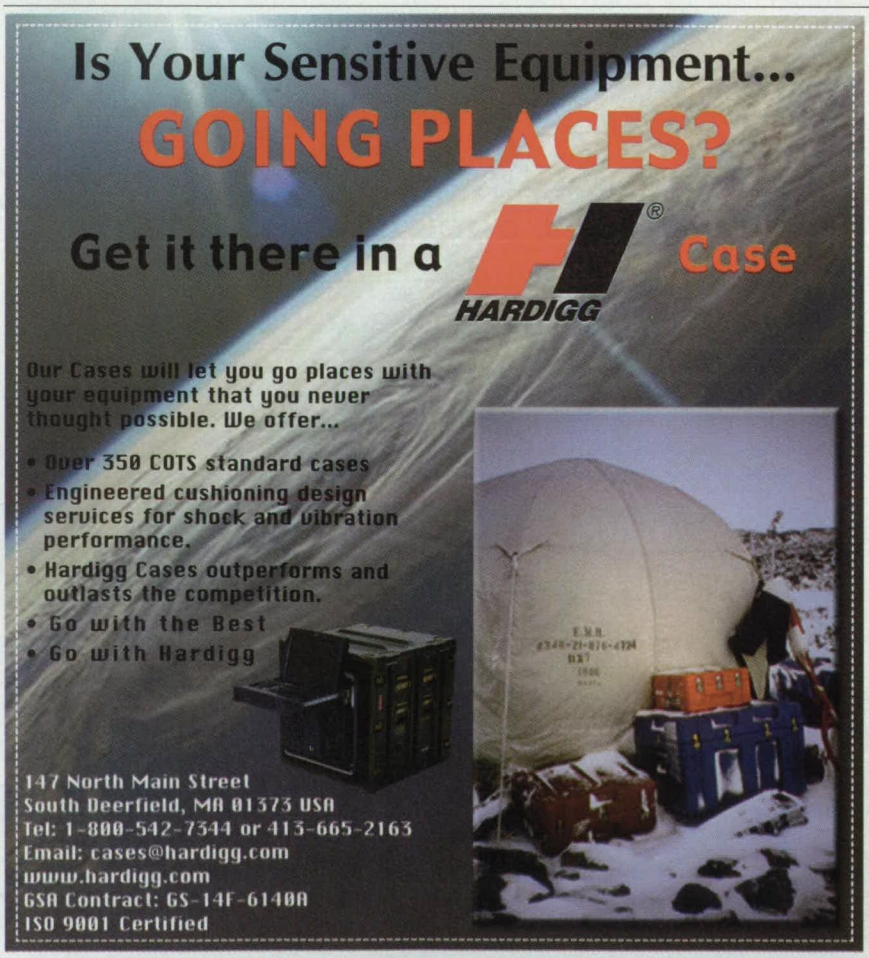
A polymer resin and fibers are laid up on the glass plate. A vacuum bag that extends past the edges of the glass plate is placed over the layup, and is then sealed to the aluminum substrate (see figure). Then the bag is evacuated, and the resin is cured in the traditional way.

Glass cure plates offer several advantages over aluminum ones:

- Glass plates as supplied by manufacturers are adequately flat and smooth; no additional surface finishing is necessary.
- The cost of a glass plate is only about 5 percent of the cost of an aluminum plate of similar size and surface quality.
- Glass is expendable and can be replaced economically if damaged, whereas aluminum must be resurfaced.
- Being harder than aluminum, glass is less vulnerable to scratching and gouging.
- The CTE (coefficient of thermal expansion) of glass matches the CTE of composite materials more closely than does the CTE of aluminum. The cure cycle, therefore, subjects the composite to less stress and risk of damage.

This work was done by James E. Baker of **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*

GSC-14040



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Spectrum Astro is pleased to congratulate the U.S. Air Force Research Laboratory on the flawless launch and continued good health of its MightySat II.1 satellite. Since its picture-perfect launch on July 19, 2000, MightySat II.1 has carried out all initial functions with a robust performance that honors the exceptional efforts of the AFRL and its many teammates: Luna, SEAKR, Kestrel, Orbital Sciences, SMC/TE, the Aerospace Corporation, the Naval Research Laboratory, Composite Optics and Jackson & Tull. Together, we're breaking new ground by enabling the transition of some of the nation's most advanced technologies in imaging, communications and space control from the laboratory to space flight operations. With innovative bus components that are lighter, smarter, and more efficient than the current standards, and stand-alone experiments that include a Fourier Transform Hyperspectral Imager, MightySat II.1 ensures a high-payoff return for this joint Defense Department Space Test Program and AFRL mission. What's more, this space-based platform is flexible enough to deliver the technological edge again and again over the course of the MightySat II multi-mission program. Reliably and affordably. And with performance that is worthy of the name, MightySat.

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Modifications of a Hydrazine Fueling Procedure and Equipment

Workers could safely wear less-restrictive protective garments.

NASA's Jet Propulsion Laboratory, Pasadena, California

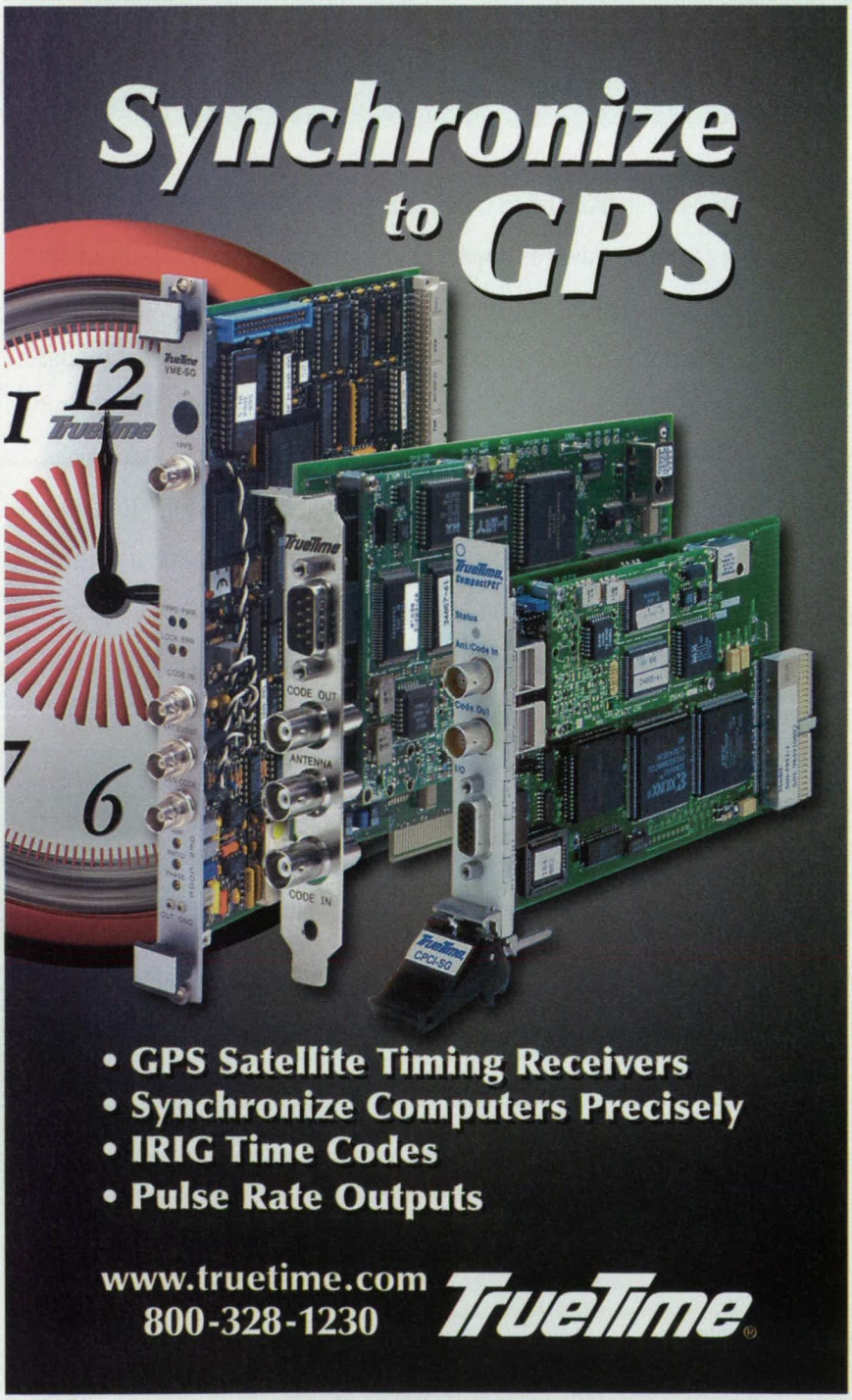
A combination of procedure and equipment for loading liquid hydrazine into a spacecraft fuel tank that contains a diaphragm or bladder would be modified, according to a proposal. The purpose of the modifications is to enable fueling technicians to work safely, during all but a small part of the loading process, in less-restrictive protective attire.

Heretofore, for reasons too complicated to describe in this article, the task of loading hydrazine into fuel tanks that contain diaphragms has posed such a high risk of leakage and spillage of hydrazine that technicians engaged in this task have been required to wear protective garments called Self-Contained Atmospheric Protection Ensemble (SCAPE) suits, which are bulky and which restrict movement so much as to make the simplest tasks difficult. Recently a combination of equipment and a procedure that entails the wearing of less-restrictive, less-protective splash suits has been developed; however, this combination is applicable only to tanks that do not contain diaphragms. The essence of the proposal is to modify this recently developed combination to make it safe to load a tank that contains a diaphragm while wearing splash suits instead of SCAPE suits during most of the loading process.

The proposed modifications address two concerns that bear on safety — again, for reasons too complicated to describe in this article. These concerns are the following:

1. A pressurant gas (ordinarily, helium) is used. This gas must be prevented from entering the spacecraft fuel tank on the fuel side.
2. The equipment includes, among other things, a fuel-supply tank and a transfer tube called the "flexline." Once the spacecraft fuel tank has been loaded, the flexline must be purged with the pressurant gas to blow liquid hydrazine back into the fuel-supply tank.

According to the proposal, the equipment would be modified by three additions: (1) a liquid/gas detector would be incorporated into the flexline between the fuel-supply tank and a service valve on the spacecraft fuel tank, (2) an automated valve controlled by the liquid/gas detector would be incorporated into the flexline between the service valve and the liquid/gas detector (see figure), and (3) a new purge fitting would be installed at the service valve.



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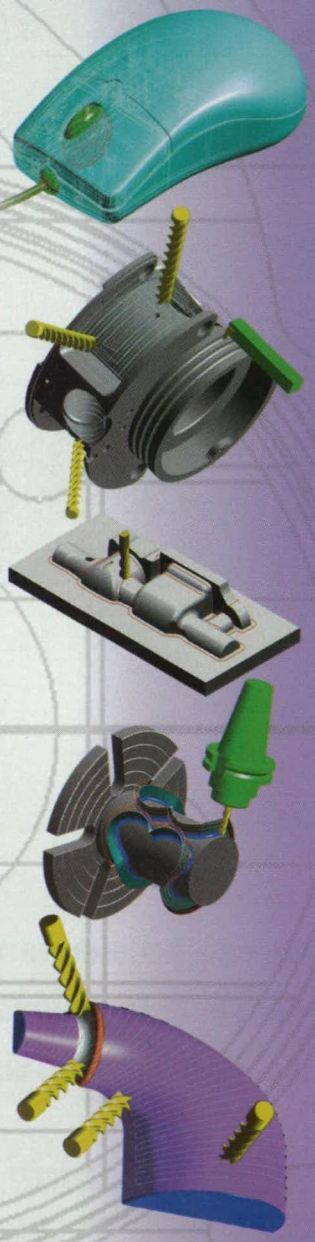

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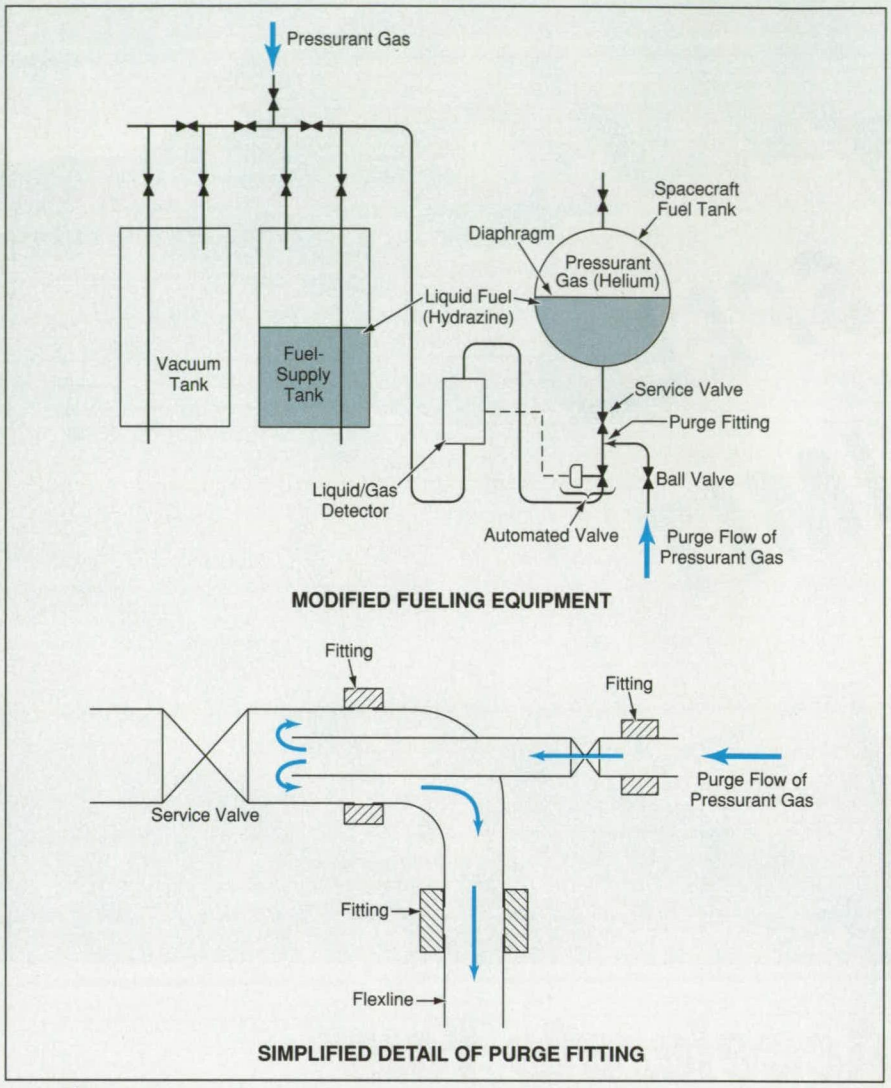

A **Liquid/Gas Detector**, an automated valve controlled by the detector, and a new purge fitting would be added to the equipment designed previously for loading a tank that does not contain a diaphragm.

The liquid/gas detector would indicate whether the flexline holds liquid hydrazine or pressurant gas. The liquid/gas detector could be a capacitance, optical-density, flotation, or other sensor. If the fuel-supply tank were to become depleted during a transfer of liquid hydrazine from the fuel-supply tank to the spacecraft fuel tank, then the pressurant gas would begin to travel along the flexline toward the spacecraft fuel tank, posing a risk that the pressurant gas might undesirably enter the spacecraft fuel tank on the fuel side. To prevent the pressurant gas from entering the spacecraft fuel tank, the liquid/gas detector would generate a command to close the automated valve as soon as it sensed the arrival of helium gas. As a result, the portion of the flexline between the liquid/gas detector and the spacecraft fuel tank would be occupied by liquid hydrazine; that is, the pressurant-gas/liquid-hydrazine front would have been prevented from traveling farther along the flexline.

At this point, it would be necessary to close the service valve: This operation would have to be performed in a SCAPE suit because there would be liquid hydrazine under pressure behind the service valve; in other words, the technicians would be only one service valve away from liquid hydrazine under pressure. Next, the liquid/gas detector would be turned off, causing the automated valve to open. The pressurant gas would then be supplied through a ball valve and the purge fitting; the flow of helium would push the liquid hydrazine in the flexline back into the fuel-supply tank. The remaining cleanup of the hydrazine-contaminated pressurant gas in the flexline could then be performed in a manner similar to that of the unmodified combination of procedure and equipment.

This work was done by John Houseman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

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Ultrasonic Bubble-Sizing Instrument

Bubbles associated with decompression sickness can be detected noninvasively.

Lyndon B. Johnson Space Center, Houston, Texas

An ultrasonic instrument has been developed for measuring the sizes of bubbles in the human body. A primary example is that of bubbles associated with decompression sickness (the "bends"); these bubbles consist mostly of nitrogen and can occur in both blood vessels and extravascular tissues. The bubbles can lodge (embolize) in vessels in the lungs and elsewhere, causing any of a variety of pathological conditions. Gaseous emboli that cause decompression sickness pose a serious risk of injury to aviators, astronauts, divers, and other individuals who are exposed to varying environmental pressures. Gaseous emboli can also be serious complications of cardiopulmonary bypass operations, introduction of air during cardiotomy, and cavitation bubbles generated by replacement heart valves.

The present instrument can be expected to aid research on decompression sickness and other gaseous embolic events by providing a capability to: (1) distinguish between gaseous and thrombotic emboli, and (2) measure the sizes of gaseous emboli noninvasively. It could be useful in research on heart valves, development of coronary-bypass machines, and cardiotomy.

The physical basis of the instrument is the use of ultrasound to excite the resonant behavior (oscillatory expansion and contraction) of gaseous emboli. The resonant behavior is a function of the bubble diameter and has been well characterized analytically, so that little or no calibration of the instrument is needed. Nongaseous (e.g., thrombotic) emboli do not display the same resonant characteristics as do gaseous emboli; this difference can be a means for distinguishing between the two types of emboli.

The instrument includes several ultrasonic transducers. One of them, denoted the pump transducer, is driven at a relatively low ultrasonic frequency (f_p) and is used to excite the fundamental vibrational mode of any bubbles that may be present. The other transducers are operated at a higher carrier frequency (f_i) in a pulse/echo mode and are part of an ultrasonic imaging subinstrument used to observe bubbles as they resonate. The instrument also includes signal-processing and -analysis equipment.

To interrogate the measurement volume for a particular bubble size, one simultaneously insonifies the measurement volume with (1) a pump signal with f_p set at the resonance frequency for that bubble size and (2) the higher-frequency imaging signal. Properly excited, the bubbles respond nonlinearly to the ultrasonic signals. In this case, they act as signal mixers; consequently, measurable signals at $f_i + f_p$ and $f_i - f_p$ are present in the high-frequency return signal if and only if there is a gaseous bubble with a fundamental resonance frequency equal to f_p. The range of bubble sizes of interest is scanned by varying f_p frequency over the appropriate range.

This work was done by Patrick J. Magari, Robert Kline-Schoder, and Brant Stoedefalke of Creare, Inc., for **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22980.

Analyzing Time Series Using EMD and Hilbert Spectra

Complicated sets of data can be decomposed into finite collections of intrinsic mode functions.

Goddard Space Flight Center, Greenbelt, Maryland

A recently developed theoretical and computational method is especially well suited for analyzing time-series data that represent nonstationary and nonlinear processes. The method stands in contrast to classical methods, including Fourier analysis, that are generally applicable only to periodic or stationary data that represent linear processes. The present method is based principally on the concept of empirical mode decomposition (EMD), according to which any complicated set of data can be decomposed into a finite (and often small) number of functions, called "intrinsic mode functions" (IMFs), that admit well-behaved Hilbert transforms.

This decomposition method is adaptive and, therefore, highly efficient. The main innovations embodied in this method are (1) the introduction of the IMFs, which are based on local properties of the signal to be analyzed and which give meaning to the concept of instantaneous frequency; and (2) the introduction of instantaneous frequencies for complicated sets of data, which frequencies eliminate a need for spurious harmonics to represent nonlinear and nonstationary processes.

Without going into detail that would exceed the scope of this article, an IMF can be loosely defined as an oscillation mode that is embedded in the data to be analyzed and that is associated with a local time scale of the data. An IMF need not be a narrow-band signal; it can be amplitude- and/or frequency-modulated and can even be nonstationary. The formal criteria for identifying an IMF are that (1) in the whole set of data, the numbers of extrema and zero crossings must be equal or differ by 1 at most, and (2) at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima must be zero.

The decomposition for a given set of data is based on direct extraction of the energies associated with various time scales and can be viewed as an expansion of the data in terms of the corresponding IMFs, which are derived from the data. The expansion can be linear or nonlinear, as dictated by the data, and it is complete and almost orthogonal. Most important, because the IMFs are derived from the data, the expansion is adaptive.

The locality and adaptivity are necessary for expanding nonlinear and nonstationary time series. The local energies and the instantaneous frequencies derived from the IMFs through Hilbert transforms can be used to construct a full energy-frequency-time distribution of the data. Such a distribution is denoted a Hilbert spectrum.

The EMD is based on three assumptions: (1) the signal has at least two extrema — at least one maximum and at least one minimum, (2) the characteristic time scale is defined by the time between the extrema, and (3) if the data are devoid of extrema but contain inflection points, then the data can be differentiated once or more times to reveal extrema. Final results can be obtained by integration(s) of the components.

The essence of the EMD is to identify the intrinsic oscillatory modes by their characteristic time scales, then decompose the data accordingly. The time scales are identified as the intervals between the successive alternations of local maxima and minima and by the intervals between successive zero crossings. The interlaced local extrema and zero crossings contribute to the complicated set of data to be analyzed: one undulation rides on another, and they, in turn, ride on still other undulations, and so on. Each of these undulations defines a characteristic scale of the data; it is intrinsic to the process.

The IMFs are extracted from the data in a sifting process (see figure). By virtue of the definition of "IMF", the decomposition can be effected simply by use of the envelopes defined by the local maxima and minima separately. Once the extrema are identified, all the local maxima and minima, respectively, are connected by a cubic spline line as the upper and lower envelope, respectively. The upper and lower envelopes should cover all the data between them. Their mean is designated as m_{10}. The difference between the data and m_{10} is denoted the first component, given by $h_{10} = X(t) - m_{10}$, where $X(t)$ is the datum at time t.

Ideally, h_{10} should be an IMF. In reality, overshoots and undershoots are common; they can generate new extrema

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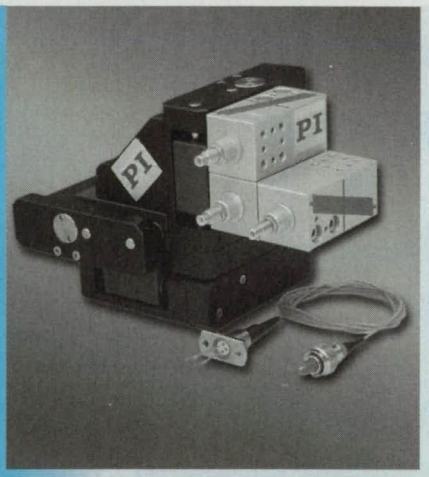

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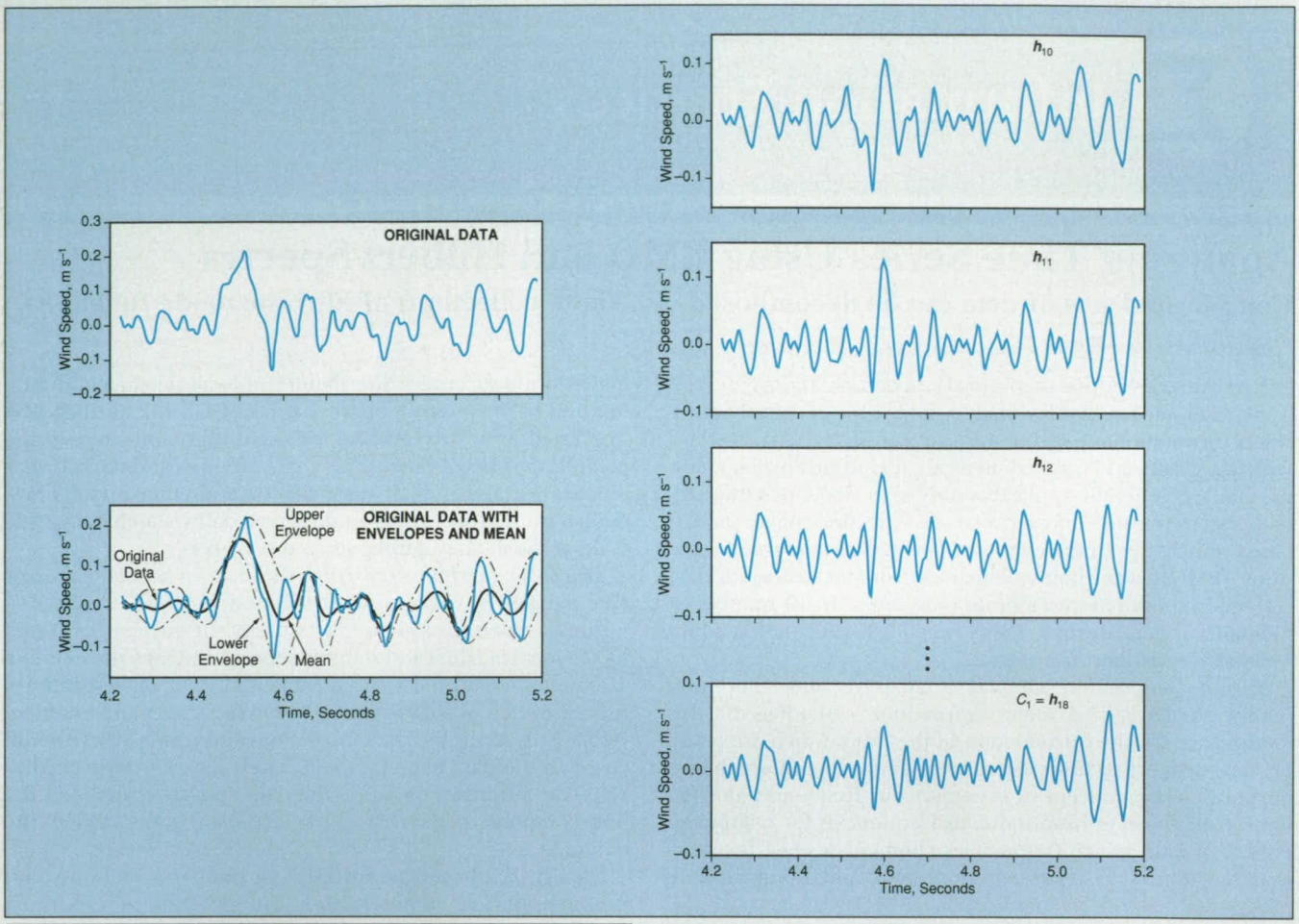

The **Original Data Are Sifted** in the multistep process described in the text to obtain the first IMF component.

and shift or exaggerate previously discovered extrema. There can remain negative local maxima and positive local minima. Thus, it becomes necessary to repeat the sifting, using h_{10} as the data: $h_{11} = h_{10} - m_{11}$, where m_{11} is the local mean of the upper and lower envelope of h_{10}. In general, it may be necessary to perform the sifting k times to arrive at the first IMF component, $c_1 = h_{1k} = h_{1(k-1)} - m_{1k}$. In the example of the figure, it is necessary to repeat the sifting up to $k = 9$ to obtain the first IMF component; that is, $c_1 = h_{18}$.

The first IMF component should be the one associated with the shortest time scale in the data. The second IMF component (c_2) associated with a longer time scale, is obtained by sifting the first residue signal $r_1 = X(t) - c_1$. In general, the nth IMF component (c_n for $n>1$), associated with a time scale longer than that of the $(n-1)$st component, is obtained by sifting $r_n = r_{n-1} - c_n$. The sifting can be stopped when either of the following criteria is satisfied: (1) c_n or r_n becomes smaller than a predetermined minimum value of substantial consequence or (2) r_n becomes a monotonic function from which no more IMF can be extracted. The sift process can be used as a time-domain filter.

This work was done by Norden E. Huang and Steven Long of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13817.

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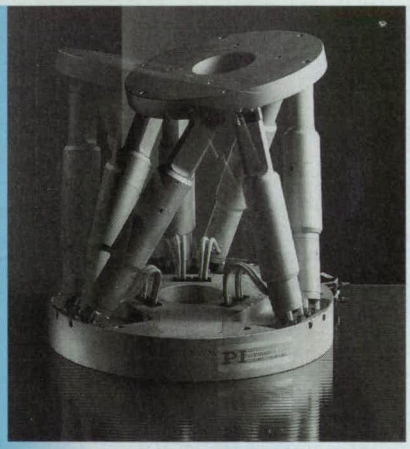
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Books & Reports

Development of Progressive-Failure-Analysis Software

A report discusses the development of the GENOA-PFA computer program, which was described in "Software for Simulating Progressive Fracture in Braided PMCs" (LEW-16845), *NASA Tech Briefs*, Vol. 24, No. 3 (March 2000), page 52; and "Update on a Progressive-Failure-Analysis Software System (LEW-16858)" *NASA Tech Briefs*, Vol. 24, No. 7 (July 2000), page 67. To recapitulate: GENOA-PFA (a commercial version of the CODSTRAN program) implements a progressive-failure methodology. On the bases of material-property data, finite-element mathematical models, and service conditions, GENOA-PFA simulates the progression of damage ultimately leading to fractures in matrix/fiber composite materials, including complex ones in which the fibers are incorporated in two- or three-dimensional weaves or braids.

This work was done by Frank Abdi of Alpha Star Corp. and Levon Minnetyan of Clarkson University for **Glenn Research Center**. *To obtain a copy of the report, "Development of GENOA Progressive Failure Parallel Processing Software Systems," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17045.

Surface and Gas Temperatures via Multiwavelength Pyrometry

A report describes experiments using multiwavelength pyrometry to determine the surface temperature of the end tip inside a BeO cylinder that is part of a probe designed to measure high-temperature gases. The cylinder is heated by the gas into which it is inserted, and the gas temperature is related to the tip temperature via a mathematical model of the probe. The probe was tested in two atmospheric burner experiments. The measured interior temperatures were 1,360 and 1,745 K. Available temperature information on the burner flame is lower, being at 1,300 and 1,580 K, respectively. This was so because the thermocouples performing the measurement were positioned at the cooler periphery of the jet to avoid being destroyed by hot gases at the burner's central flow, the hot temperature of which the BeO probe was successful in measuring.

This work was done by Gustave Fralick and Daniel Ng of **Glenn Research Center**. *To obtain a copy of the report, "Pyrometric Gas and Surface Temperature Measurements," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16972.

Tribology for Aerospace Applications

"Tribology for Aerospace Applications" is a textbook and reference source written for designers of rotating machinery; users and designers of such mechanical components as bearings, gears, and seals; tribologists; university and industrial researchers; and students of machine design. The book incorporates information from more than 900 references spanning over 50 years of technological advances. The titles of the chapters are "Tribology Fundamentals," "Solid Lubricants," "Self-Lubricating Polymer Composites," "Liquid Lubricants," "Traction Lubricants," "Rolling Bearing and Gear Lubrication," "Rolling Bearing and Gear Materials," "Fluid and Gas Film Lubrication," "Engine Seals," and "System Life and Reliability."

This book was coauthored and edited by Erwin V. Zaretsky of **Glenn Research Center** *in collaboration with the staff of Glenn Research Center and the Society of Tribologists and Lubrication Engineers. Copies of the book can be ordered from Society of Tribologists and Lubrication Engineers, 840 Busse Highway, Park Ridge, IL 60068-2376; telephone (847) 825-5536; fax (847) 825-1456.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17028.

Advances in Plastics Influence Design

New materials technology and advanced plastics have spurred the growth of many new products, including the lead screw with plastic nut.

Advances in materials have accounted for the growth of many new industries. Lead screw systems using polymer nut technology have been developed to the current state of the art largely in the past 20 years. The advent of inexpensive, high-performance, bearing-grade polymers has fueled the linear motion marketplace with the ability to move loads quickly and accurately.

No such advance in materials has been seen in the recirculating ball bearing screw industry. This has resulted in only evolutionary changes in the original design from the 1950s. Ball screw technology is based on the recirculating ball mechanism, while polymer lead nut technology relies heavily on the properties of the mating materials to produce the desired thrust load. Since the materials themselves are doing more, fewer components are required, simplifying the design and reducing costs.

Plastics Come of Age

In 1960, one of the most important engineering plastics became available under the trademark Delrin®. Delrin is a homopolymer acetal resin, synthesized through the polymerization of formaldehyde. It was termed the most "metal-like" plastic due to its strength and rigidity, allowing it to perform many functions that only metals had performed previously. Although the base acetal resin is well suited for many structural applications, the addition of a filler into the resin would soon make it an important bearing-grade material.

By itself, the fluorocarbon family is a poor structural material, with a tendency to creep under load even at room temperature. But when the PTFE fluorocarbon — more commonly known as Teflon® — is added to a stable substrate, a material with excellent tribological properties is produced.

Because the materials do more, the mechanism of a typical polymer lead nut is simplified. This allows for production in a wide variety of geometries to meet specific application requirements.

The ability to compound PTFE into a polymer such as acetal and mold shapes to net size is a powerful tool for designers. This technology has spurred the growth of many new products, one of which is the lead screw with plastic nut.

Lead Nuts Go Plastic

The plastic nut industry began to burgeon in the early 1980s as it became clear to the marketplace that there was a definite application for this technology. Unlike recirculating ball bearing screws, lead screws could be produced in soft stainless steel. This allowed for their use in clean and environmentally harsh environments. The nut itself became the bearing, using internally lubricated plastics to provide surprising high load capability. System complexity was reduced by using the properties of the plastic itself to do the work. Best of all, these clean, precise, and simple devices were considerably more cost-effective than traditional ball bearing technology — anywhere from one-half to one-fifth the cost of a comparable ball screw. But with any technology, the boundaries of load and speed were pushed.

In the 1970s, two new plastics arrived on the scene. They offered "PV" (pressure velocity) limits of five to ten times that of acetal. PV is a measure of a material's ability to be dynamically loaded. The more load that is applied to a material, the lower the sliding velocity that it can handle, and vice versa. The PV limit of a material is the point at which friction-generated heat can no longer be expelled at a rate to prevent the material from overheating. Torlon®, a polyamide-imide, and a polyimide known as Vespel® arrived on the scene just in time. They can both be compounded with lubricants such as PTFE and function well as bearing materials with the additional advantage of having high PV limits. Unfortunately, they are much more expensive than acetal and are not readily moldable due to their high melt temperatures (in the neighborhood of 800 °F).

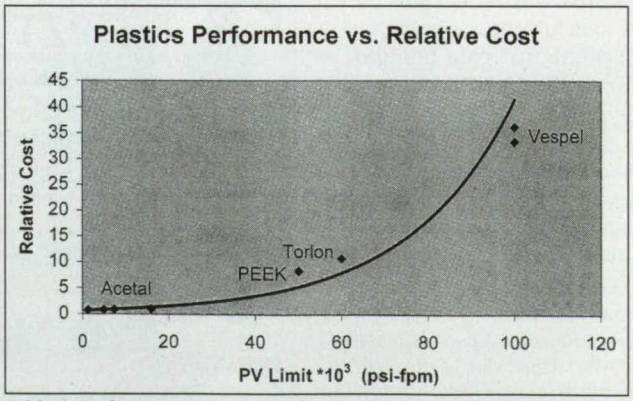
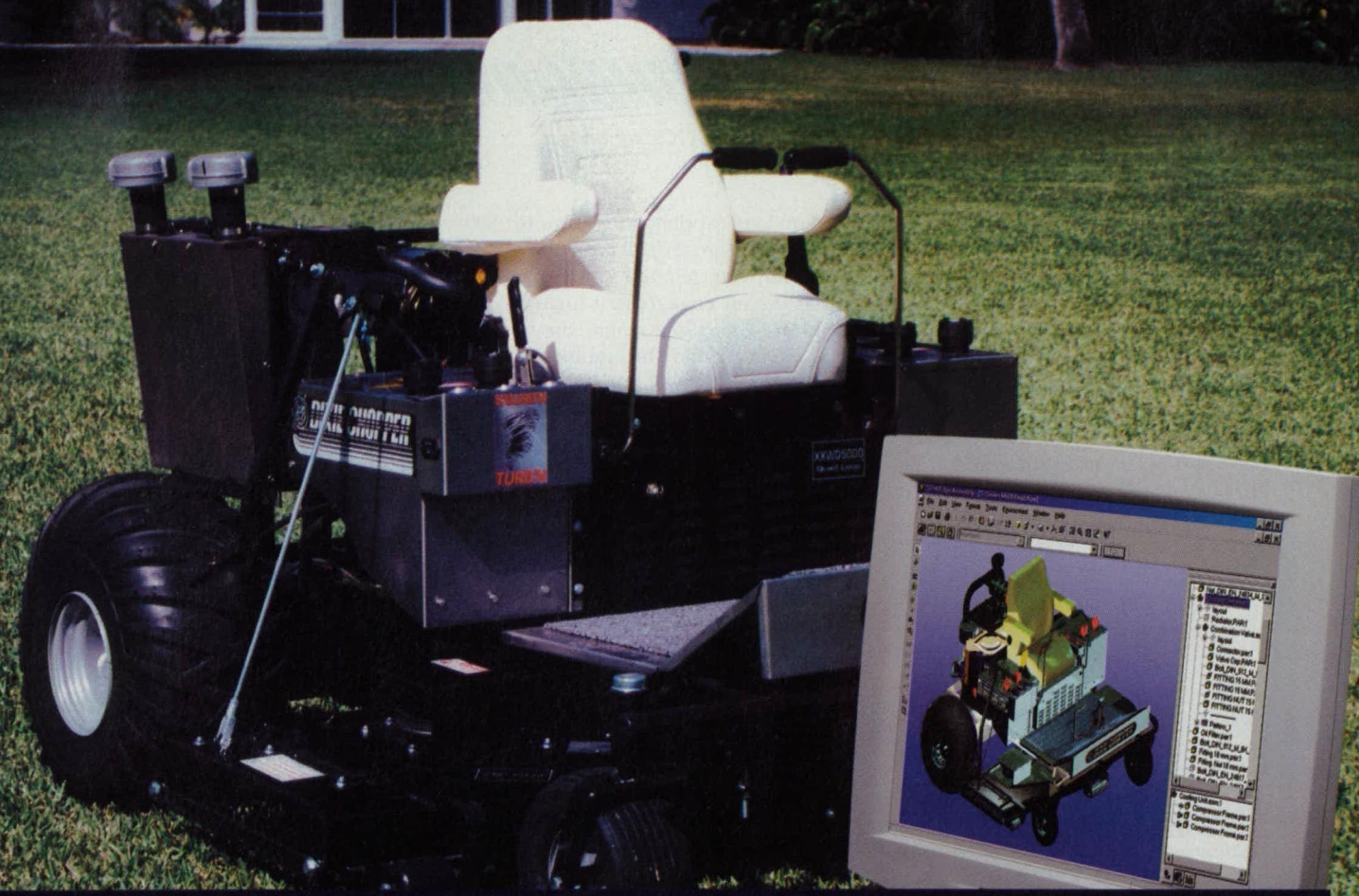


Table 1: Performance versus cost for plastics is not a linear relationship. Avoid over-specifying polymers as their cost increases geometrically with performance.

As recently as the late 1980s, a plastic known as PEEK became available. It has properties similar to polyamide-imide, but is moldable at high temperatures. All of the standard lubricants can be compounded to produce a very flexible, high-performance plastic. Cost is greater than acetal, but more reasonable than polyimide.



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New Design Applications

These material advances have allowed lead screws to be used where they never could have before. It is now possible to tailor the performance of a lead screw system to meet demanding load, speed, environmental, and space requirements. The majority of plastic nut applications use acetal with PTFE. With a PV of about 13,000 psi-fpm, and an attractive price point, this material works well in light- to medium-load applications (up to 300 pounds). Design engineers can specify almost any nut geometry having the required thread engagement for their application. This allows engineers to integrate what would be multiple components with a traditional lead screw into a single part, saving space, money, and assembly time. It also allows the designer to shrink the overall package size. Acetal can be easily machined or molded to produce complex shapes. Since the material is the bearing, the nut diameter can be held to a minimum, and generally is a function of the manufacturability of the part and the ability to fixture it in the application.

Self-lubricating polymers give lead screw assemblies the ability to operate in clean environments. Their simplified mechanism (compared with ball screws) makes them cost-effective while advances in materials allow more aggressive operation than previously possible. This has made them popular in such industries as medical and semiconductor.

In many cases, the plastic must perform as both a bearing element and a structural element. Although this is always true to some extent, as the geometry becomes more complex, acetal may not offer the required stiffness or strength. In this case, additional fillers such as carbon fibers can be compounded in, enhancing the structural properties. Carbon fiber has the benefit of good tribological properties as well.

Acetal is suitable for many demanding applications ranging from marine to cleanroom usage. For loads above 300 pounds and speeds greater than 1,000 rpm, acetal hits its PV limit, depending on screw size and lead. With a PV of about 50,000 psi-fpm, PEEK can extend this range. Speeds of 5,000 rpm and more are possible. Normally, to achieve fast jog speeds, the designer is forced to go to a high lead screw, limiting their system accuracy. PEEK can allow engineers to design systems with a fine screw pitch for good resolution, while still having the necessary jog speed to meet cycle-time requirements.

In the same vein as PEEK, polyamide-imides (Torlon) allow greater load and speed with a PV of around 60,000 psi-fpm. Unfortunately, polyamide-imides are not easily molded. Although the cost is only marginally greater than PEEK, fabrication may be more difficult. Polyimide (Vespel) offers the greatest PV of all at around 100,000 psi-fpm. It has a low coefficient of thermal expansion as well (between 21 and 30 × 10^{-6} in/in/°F).

If nothing else will work, polyimide may be the answer. Cost increases dramatically with polyimide and it is not moldable, although it can be sintered into basic shapes. Always weigh the cost benefit ratio carefully when using a polyimide. Cost increases dramatically with diameter. Expect to be spending on the order of $20 per inch for a 3/4" bar. Additionally, polyimide performs best when run against a hardened surface. This increases the cost of the mating component as well. Lead nuts made of polyimide with molybdenum disulfide filler have been used in space applications due to their lubricity and thermal stability (PTFE's lubricity decreases in a vacuum). Polyimide's high strength-to-weight ratio makes it well suited for mass critical applications.

Plastics have allowed lead screws to go from the depths of the ocean to the reaches of outer space. Improvements in materials have fueled advancements in almost every technology. If material development keeps pace in the next century, materials will continue to solve problems that design alone cannot.

For more information, contact the author of this article, Robert Lipsett, Vice President of Engineering, Ball Screws & Actuators, San Jose, CA; Tel: 408-363-7128; e-mail: rlipsett@ballscrews.com; or visit www.ballscrews.com.

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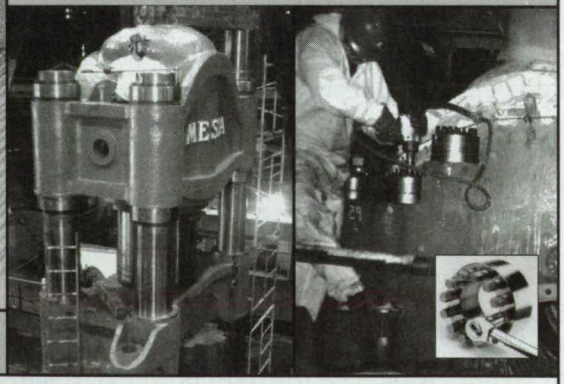

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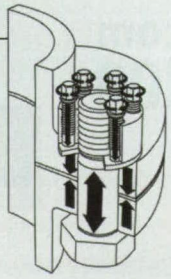

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SiC/SiC Composites With Improved BN Coating on Fibers

The *in-situ* BN coating helps to deflect cracks away from the fibers.

John H. Glenn Research Center, Cleveland, Ohio

A method of fabricating composites of pretreated silicon carbide fibers in silicon carbide matrices provides for the formation of improved boron nitride fiber/matrix interfacial layers. As explained below, these BN layers help to deflect matrix cracks away from the fibers.

In order to impart strength and fracture toughness to a fiber/matrix composite material, one must formulate it so that under high stress, it fails in a fiber-pullout mode rather than a brittle-fracture mode. This requirement translates to a need for a fiber/matrix interfacial layer of a material (denoted the "interphase") that is weakly bonded to both the fibers and the matrix to insure that matrix cracks are deflected away from the fibers.

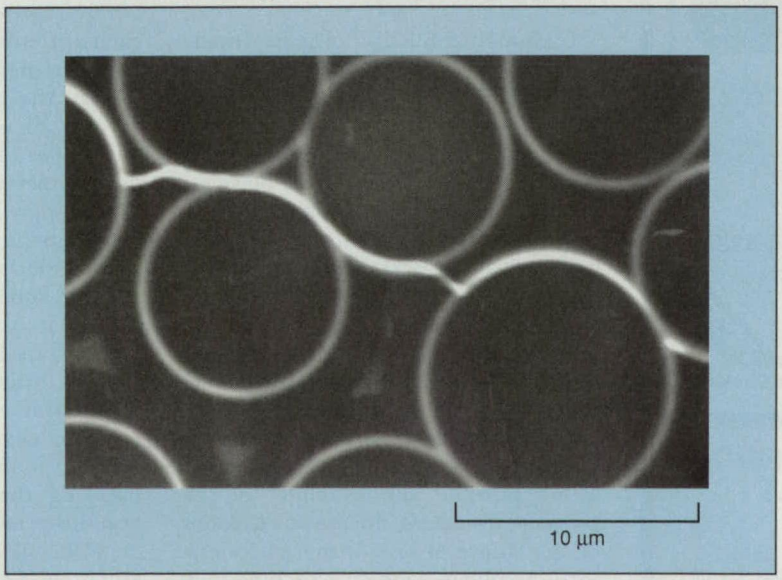
One of the most widely used fiber/matrix interphases is boron nitride, which, heretofore, has usually been deposited on fibers or fiber preforms by chemical vapor deposition (CVD). One of the drawbacks of the CVD BN process is that when a tow (a bundle that normally consists of between 500 and 800 fibers with diameters between 10 and 15 μm) is formed into a woven fiber preform prior to CVD BN coating, many of the fibers are in contact with each other and therefore do not become completely coated with BN. On subsequent fracture of the composite, those fibers that are in contact with no BN between them tend to fail in a brittle manner, with little or no fiber pullout. This situation is exacerbated if the SiC fibers have relatively rough surfaces (as some commercial SiC fibers do). In addition, ordinary CVD BN fiber coats are not particularly crystalline, and have been found to be very susceptible to oxidation in hot, moist environments like those in gas turbine combustors.

In the present method, thin layers of either (1) carbon-rich SiC containing some boron or (2) highly crystalline BN are formed *in situ* on the SiC fibers, before further processing; these layers prevent the SiC fibers from remaining in contact with each other. Because these thin surface layers are not thin enough (and, in the case of highly crystalline BN are not weak enough) to act by themselves as crack-deflecting layers, it is necessary to deposit BN overcoats (with or without Si doping) by chemical vapor infiltration to obtain the desired crack-deflection property. The remaining processing steps, following conventional practice, include the formation of SiC overcoats by chemical vapor infiltration, infiltration by a slurry that contains SiC particulate, and infiltration by molten silicon at a temperature of ≈1,420 °C to realize a dense matrix.

The subprocess to form the boron-doped carbon or highly crystalline BN begins with a heat treatment of the fibers at a temperature of 1,800 °C in either an inert or nitrogen gas. In the case of a nitrogen atmosphere, boron (which is present in typical commercial SiC fibers as a sintering aid) diffuses to the fiber surfaces to form thin (≈100-nm thick) layers of very crystalline BN. The added advantage of diffusing the boron out of the fibers is that the resistance to creep of the fibers at high temperatures is increased. In the case of an inert atmosphere, the surfaces of the fibers become reduced, with resultant formation of thin (≈50 to ≈100 nm thick) carbon-rich surface layers, which also contain some boron from diffusion out of the bulk.

When the fibers that have been thus heat treated are subsequently woven into cloth preforms or are heat-treated in cloth form, the highly crystalline BN or carbon-rich surface layers prevent the SiC fiber cores from touching. While carbon-rich fiber surface layers may prevent the fibers from touching, they are not desired because they do not exhibit sufficient resistance to oxidation as that of the BN layers.

The highly crystalline layers of BN are strongly bonded to the fiber surfaces, and prevent the propagation of cracks from the matrix into the fibers (see figure). By keeping the fibers out of contact, the highly crystalline layers also prevent interlocking of the rough fiber surfaces. The highly crystalline nature of these layers also contributes to stability under stress in an oxidizing environment.



A Matrix Crack Has Been Diverted Around Three Fibers at the interfaces between (1) the highly crystalline *in situ* BN layers and (2) the CVD BN layers at the fiber/matrix interfaces.

This work was done by James A. DiCarlo and Hee Mann Yun of **Glenn Research Center** *and John J. Brennan of United Technologies. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

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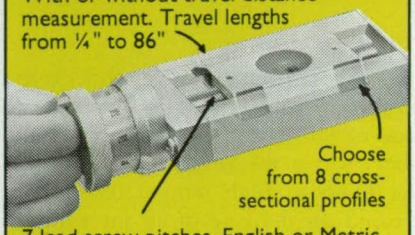

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Silica-Filled EPDM Rubbers as Ablative Insulating Materials

These materials are intended to replace other materials that will soon be unavailable.

Marshall Space Flight Center, Alabama

Silica-filled polymers made from ethylene propylene diene monomer (EPDM) have been found to be useful as ablative thermal-insulation materials. These polymers have been investigated as candidates to replace some previously developed polymeric ablative rocket-engine insulating materials that will soon become commercially unavailable. Although these materials have been developed specifically for use in and on solid-fuel rocket motors, they may also be useful in terrestrial applications in which there are requirements for protection against high temperatures for short times.

Several formulations of silica-filled EPDM polymers have been investigated. These formulations incorporate improvements where possible. Examples of improvements include the use of a tackifier or the choice of one or more accelerator(s) to obtain a longer scorching time as well as desired curing properties. For each formulation, the ingredients are mixed according to ordinary rubber-processing techniques in a two-pass mixing procedure implemented in an internal mixer. All the ingredients except the accelerator(s) and sulfur (if used) are added during the first pass; the accelerators and sulfur (if used) are added during the second pass. In ablative tests, some formulations unexpectedly performed better than others did.

This work was done by David G. Guillot of Thiokol Corp. for **Marshall Space Flight Center**. *For further information, please contact the company at guilldg@thiokol.com.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)} to Thiokol Corporation. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to MFS-31406, volume and number of this NASA Tech Briefs *issue, and the page number.*

Carbon-Filled EPDM Rubbers as Ablative Insulating Materials

These materials are intended to replace other materials that will soon be unavailable.

Marshall Space Flight Center, Alabama

Carbon-fiber-filled polymers made from ethylene propylene diene monomer (EPDM) have been found to be useful as ablative thermal-insulation materials. Like the silica-filled EPDM polymers described in the preceding article, these polymers have been investigated as candidates to replace some previously developed polymeric ablative rocket-engine insulating materials that will soon become commercially unavailable.

Several formulations of carbon-fiber-filled EPDM polymers have been investigated. As in the case of the silica-filled polymers described in the preceding article, improvements are incorporated where possible and examples of improvements include the use of a tackifier or the choice of one or more accelerator(s) to obtain a longer scorching time as well as desired curing properties. For each formulation, the ingredients are mixed in the following procedure:

First, the ingredients are mixed according to ordinary rubber-processing techniques in a two-pass mixing procedure implemented in an internal mixer. All the ingredients except the accelerator(s) and sulfur (if used) are added during the first pass, and the accelerators and sulfur (if used) are added during the second pass. The resulting mixture is dissolved in a suitable solvent such as hexane. The solution is then mixed with carbon fibers, using a minimum of mixing to disperse the fibers and distribute them uniformly without breaking them excessively. The solution/fiber mixture is then spread thin on a flat sheet so that the solvent can evaporate (if desired, evaporation can be done in an oven). The resulting un-

cured insulating material is then cured in the required shape.

In ablative tests, some of the formulations investigated performed a little better than others did, probably because of differences in mixing.

This work was done by David G. Guillot of Thiokol Corp. for **Marshall Space Flight Center.** *For further information, please contact the company at guilldg@thiokol.com.*

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Graphite/Conductive-Epoxy Electromagnetic Shielding

Shielding ability equals that of a larger mass of aluminum.

John H. Glenn Research Center, Cleveland, Ohio

Lightweight shields for electromagnetic interference (EMI) can now be fabricated from composites of (1) electrically conductive fibers made of bromine-intercalated graphite in (2) matrices of electrically conductive epoxy. As shown in more detail below, the shielding ability of a given thickness of this composite material equals that of a greater thickness of aluminum.

Electrical conductivity of surface layers is essential for EMI shielding. Previously, NASA had developed EMI shields made of bromine-intercalated graphite fibers in matrices of electrically insulating epoxy. However, those shields were not as effective as aluminum shields because of the lack of electrical conductivity in the epoxy (especially in surface layers).

The table compares the shielding effectiveness of a sheet of aluminum and a sheet of the present bromine-intercalated-graphite-fiber/electrically-conductive-epoxy composite. On the basis of performance figures like those in this table, it has been estimated that by use of this composite material, it should be possible to make EMI shields thinner than aluminum shields (which are typically about 2 mm) but equally as strong and equally as effective against EMI. It has been further estimated that reductions in weight, relative to aluminum shields, can be expected to lie between 34 and 88 percent.

Material	Transmission at Test Frequency of 35 GHz, dB	Transmission at Test Frequency of 10 GHz, dB
Aluminum	–50	–42.9
Composite of Bromine-Intercalated Fibers in a Matrix of Electrically Conductive Epoxy	–50	–24.2

The EMI-Shielding Performances of a 2-mm thick sheet of aluminum and a 0.36-mm thick sheet of the present composite material made from electrically conductive epoxy were measured at frequencies of 10 and 35 GHz.

This work was done by John D. Lennhoff and George G. Harris of Triton Systems, Inc., for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16647.

Composite-Material Pipes for Corrosive and Cryogenic Liquids

Piping systems with complex shapes can readily be fabricated.

Marshall Space Flight Center, Alabama

A flexible design concept and an associated method of fabrication have been conceived as means to satisfy growing demands for lightweight composite-material pipes for corrosive and cryogenic liquids. The design concept and method can be applied to produce piping systems capable of handling such diverse liquids as cryogenic oxygen, hydrogen peroxide, strong acids, and strong bases. The piping systems can be complex; for example, they can include manifolds and/or pipes with multiple bends.

Fabrication begins with the molding and/or machining structural segments in basic shapes that can be assembled into a mandrel that defines the geometry of a complex piping system. The basic shapes can include elbows, T junctions, Y junctions, and flanges.

Once the shapes have been joined to form a mandrel, various composite-material layers are deposited on the mandrel to form the piping. The first layer to be deposited on the mandrel is a liner. The liner can be a single thin layer of a metal, a metal layer comprising thin sublayers of different metals, or a polymer, for example.

Multiple layers of a composite material are placed on the liner and cured. The mandrel material is then removed from inside, leaving a thin-walled composite tube structure. Next, the structure is covered by a thermal-insulation layer. If the liquid to be contained is cryogenic, then a suitable insulating material could be low-density polyurethane foam; if the liquid to be contained is hot, then a better insulating material would be a phenolic fire-resistant foam. The foam can be sprayed and later machined; alternatively, premachined foam segments can be assembled onto the piping. If needed, small channels can be machined in the foam layer to accommodate a cooling or heating manifold.

The foam layer is covered with an outer composite-material skin. Finally, the structure is heated to cure the resin in the skin.

This work was done by Thomas K. DeLay of **Marshall Space Flight Center.**

This invention is owned by NASA, and a patent application has been filed. For licensing inquiries, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at (256) 544-5226 or sammy.nabors@msfc.nasa.gov. Refer to MFS-31381.

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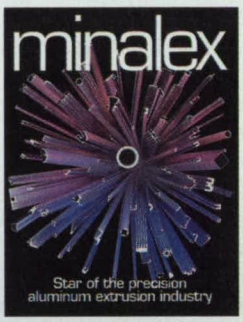

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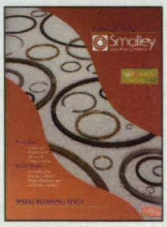

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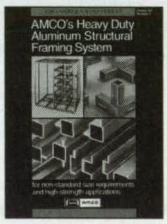

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For More Information Circle No. 620

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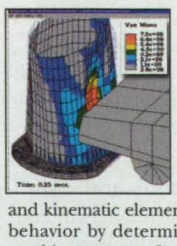

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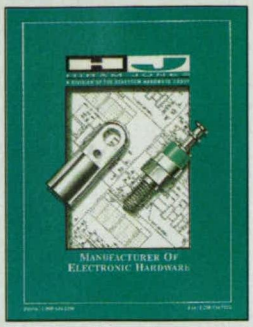

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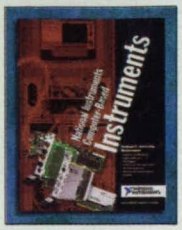

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National Instruments Computer-Based Instruments brochure describes how to automate your measurements and reduce your test time using computer-based instruments. The brochure includes technical information on digitizers/oscilloscopes, digital multimeters, high-accuracy temperature/voltage data loggers, waveform generators, FFT dynamic signal analyzers, switches, multiplexers, and matrices. Call today for your FREE brochure! National Instruments; Tel: 800-811-9526 or 512-794-0100; Fax: 512-683-9300; e-mail: info@ni.com; www.ni.com/info/instruments

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Penn Engineering

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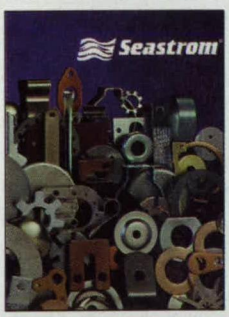

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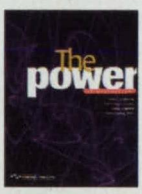

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VIBRATION ISOLATION & IMPACT ABSORPTION

New, full-color brochure describes the dynamic properties of Sorbothane, the unique vibration isolation and impact absorption material. New test data details the damping properties of Sorbothane compared to other elastomers. Sorbothane is a patented visco-elastic polymer. Includes information on Sorbothane's new line of advanced vibration isolation/shock absorption products, as well as applications engineering, manufacturing capabilities, and the many applications for Sorbothane. Sorbothane, Inc.; Tel: 330-678-9444; Fax: 330-678-1303; e-mail: webmaster@www.sorbothane.com; http://www.sorbothane.com

Sorbothane, Inc.

For More Information Circle No. 633

INDUCTOSYN® POSITION TRANSDUCERS

Our 16-page Engineering Guide describes how to select and use Inductosyn® position transducers for applications in extreme aerospace and industrial-manufacturing environments. Rotary Inductosyn® transducers provide absolute and incremental position information, accurate to ±0.5 arc second or better, with resolution to 26 bits. Linear Inductosyn® transducers are accurate to ±μ40 inches or better, with sub-μinch resolution. Farrand Controls, a division of Ruhle Companies, Inc.; Tel: 914-761-2600; Fax: 914-761-0405; e-mail: sales@ruhle.com; www.ruhle.com

Farrand Controls

For More Information Circle No. 634

LIGHTED INTERFACE SWITCH CONTROLLER-XT

Literature from StacoSwitch details the Interface Controller-XT (IFC-XT) — a flexible, low-cost digital I/O controller designed to manage clusters of lighted pushbutton switches, LEDs, and incandescent lamps. Features include 32 input and 32 output channels, audible tone generation, adjustable output levels of all lamps individually, and RS-232 and RS-422 capability; simple software driver set; compact size; easy direct mount. StacoSwitch; Tel: 714-549-3041; Fax: 714-549-0930; e-mail: sales@stacoswitch.com; www.stacoswitch.com

StacoSwitch Co.

For More Information Circle No. 635

VACUUM PUMP VIBRATION ISOLATORS

The NEC vibration isolators effectively remove turbo-molecular and cryo-pump vibrations. Two models are available in elastomer and air-isolated versions. They are UHV compatible, have short insertion lengths, and high conductance. A wide variety of flanges are available. National Electrostatics Corp., 7540 Graber Rd., Box 620310, Middleton, WI 53562-0310; Tel: 608-831-7600; Fax: 608-256-4103; e-mail: nec@pelletron.com; www.pelletron.com

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Goodfellow Corp. supplies a range of foams of interest to engineers who want to incorporate strength into their product designs without adding weight. Each foam offers a high surface area to volume ratio, as well as a high strength to weight ratio. Foams of aluminum, vitreous carbon, nickel, silicon carbide, and alumina are available. Goodfellow Corp., 800 Lancaster Ave., Berwyn, PA 19312; Tel: 800-821-2870; Fax: 800-283-2020; e-mail: info@goodfellow.com; www.goodfellow.com

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OMEGA'S TECHNICAL REFERENCE SERIES

OMEGA's Transactions and Volume MM® Master Index is a technical reference series combining measurement and control information with a comprehensive index for locating more than 100,000 OMEGA products. Each issue focuses on a particular measurement and control topic. The premiere issue, *Non-Contact Temperature Measurements*, provides information on historical and theoretical principles in addition to selection and application guidelines. Other issues include *Data Acquisition Systems; Pressure, Strain & Force*; and *Flow and Level Measurements*. OMEGA Engineering Inc., One Omega Dr., P.O. Box 4047, Stamford, CT 06907-4047; Tel: 203-359-1660; Fax: 203-359-7700; e-mail: info@omega.com; www.omega.com

OMEGA Engineering

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FREE CATALOG OF TOOLING COMPONENTS

The Reid Tool Supply catalog offers more than 40,000 items, including handwheels, handles, knobs, spring and ball plungers, vibration-isolation items, leveling pads, clamps, set-up accessories, locating devices, linear motion slides, latches, hinges, thread inserts, bearings, and more. Most items are available in inch and metric. All items are in stock for same-day shipment with no minimum-order requirement. Reid Tool Supply Co., 2265 Black Creek Rd., Muskegon, MI 49444; Tel: 800-253-0421; Fax: 800-438-1145; www.reidtool.com; IMTS Booth # E2627

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For More Information Circle No. 640

DSP LOCK-IN AMPLIFIERS

The SR810 (single phase) and SR830 (dual phase) DSP lock-in amplifiers have a frequency range of 1 MHz to 102.4 kHz and provide 100 dB of dynamic reserve without pre-filtering. Output time constraints range from 10 μs to 30 ks, with 6, 12, 18, or 24 dB/oct rolloff. A low distortion (-80 dBc) synthesized reference source and GPIB and RS-232 computer interfaces are standard. SR810 (U.S. list) $3,650; SR830 (U.S. list) $3,950. Stanford Research Systems; Tel: 408-744-9040; Fax: 408-744-9049; e-mail: info@thinkSRS.com; www.thinkSRS.com

Stanford Research Systems

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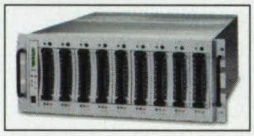
COATINGS FOR METALS RESIST ABRASION & CORROSION

Magnaplate-applied coatings that improve performance of metal parts are detailed in an 8-page Engineering Data Guide. Hardness, friction, wear, temperature, thickness, and corrosion & abrasion resistance properties of 13 super-hard, non-stick, permanent, surface enhancement coatings are described. Also includes FDA/USDA/AgriCanada approvals. General Magnaplate, Linden, NJ 07036; Tel: 800-852-3301; Fax: 908-862-6110; e-mail: info@magnaplate.com; www.magnaplate.com

General Magnaplate

For More Information Circle No. 642



SCSI ENCLOSURES

StorCase™ Technology is pleased to announce the release of a new line of external expansion chassis, the InfoStation™ backplane-design SCSI enclosure. Its direct connect backplane supports up to 9 high-density, high-speed, 3.5" SCSI single-ended, Ultra2, or Ultra160 SCA devices for RAID or JBOD applications. With upgrade slots for adding RAID and SAF-TE controller modules, the InfoStation is ready for the future when you are. StorCase Technology, a Kingston Technology Co.; www.storcase.com

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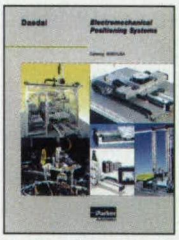

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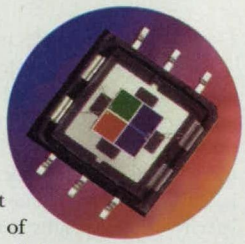
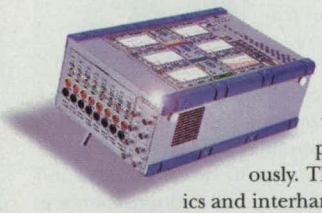
New on the MARKET

Color Sensor



The S7505 surface-mountable, three-color sensor from Hamamatsu Corp., Bridgewater, NJ, is designed with three narrow band filters mounted on a single-chip, four-element detector. It provides color separation for red, green, and blue, making it suitable for color recognition in a variety of measuring instruments. The sensor measures 9.4 x 2.0 x 9.0 mm, and has an operating temperature range from -10° to +60° C. Dark current is 10 pA and sensitivity is 0.23 A/W at 460 nm for the blue filter; 0.28 A/W at 530 nm for the green filter; and 0.45 A/W at 660 nm for the red filter. **Circle No. 730**

Power Network Analyzer



Dewetron, Charlestown, RI, has announced the PNA-3000 power network analyzer that performs several power quality measurements simultaneously. The unit is an FFT analyzer of harmonics and interharmonics, power and energy flow meter, flicker meter, voltage monitor, transient recorder, and data post-processor. Data is captured into the internal drive and displayed in real time. It is operated via a touchscreen, or with a standard keyboard and mouse. The system accepts any standard modem for remote operation. Signal conditioning and calibration are conducted in the system software. **Circle No. 731**

Precision Balances

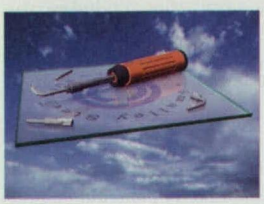
An enhanced line of BL and EL Series precision balances has been released by Setra Systems, Boxborough, MA. The balances employ variable capacitance technology and Moment Insensitive Load Cell design. Capacities range from 200 g to 4100 g. The balances feature six keys; can display weight in grams, ounces, carats, percent, and programmable user-defined units; and can display flow rate in grams per second. Single-range and dual-range models are available. **Circle No. 732**

Laser Gauging Sensor

The SLS 6000 Class II, non-contact, laser-based dimensional industrial gauging sensor from LMI Selcom, Southfield, MI, features stand-off of 400 mm, with a 50-mm measurement range, a built-in signal processor, and sampling frequency of 16,000 times per second. The sensor is adaptable for a variety of measurement applications within the rubber and associated industries, and can be used in high-speed applications. The sensor features a flat lens shield and an internal air purge system to cool the unit. **Circle No. 734**

Ring Removal Tool

Smalley Steel Ring, Wheeling, IL, offers a spiral retaining ring removal tool to remove multiple-turn rings. The tool fits between the ring layers to access the removal notch. When in place, it surrounds the removal notch and eliminates slipping as the ring's free end is pulled out radially or up for removal. The tool is available in four standard ends: small-straight, small 90° bend, large-straight, and large 90° bend. **Circle No. 735**



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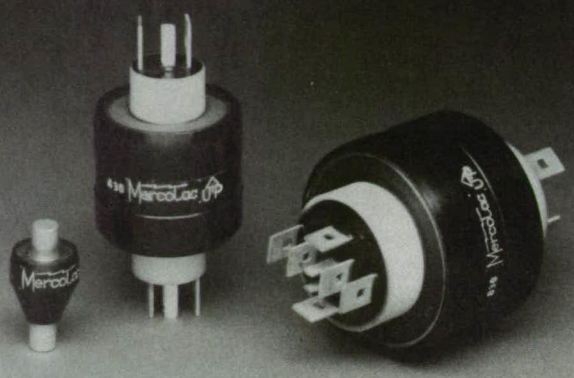
For More Information Circle No. 430

Rotating Electrical Connectors



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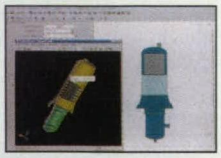
For More Information Circle No. 432

New on DISK

Design Automation

Geomate Corp., San Jose, CA, has released GrafiCalc 2.0 mechanical design automation software that synthesizes geometry, calculations, and design goals in an extendable environment. The software incorporates behavioral modeling, which enables users to solve a range of mechanical engineering problems that benefit from optimization against fit, form, functional criteria, and measured values. Users can specify desired results such as area, moment of inertia, volume, cost, weight, distance, tolerance, and stress, and the software synthesizes geometry that meets the specified design goals. **Circle No. 715**

Design/Stress Analysis



PVElite Version 4.0 pressure vessel design and stress analysis software is available from COADE, Houston, TX. The new version features a 3D model viewer, DXF file generation, and updated local stress evaluation for round hollow nozzles on spheres and cylindrical shells. The software also incorporates pressure vessel codes and standards, providing engineers, designers, and fabricators with graphical modeling capabilities for data assembly and vessel analysis. The new 3D viewer can read and render any input file, and includes real-time model rotation, zooming, panning, cutting planes, and wireframe viewing. **Circle No. 716**

Simulation/Visualization

Global Majic Software, Huntsville, AL, has introduced 3DLinx™ 1.5 language-independent simulation development software for building interactive, 3D, web-enabled models. Object-oriented coding allows a living model to be programmed with the characteristics and behaviors needed to produce realistic actions and natural interactions within an environment. The models can either be downloaded or created for use in virtual reality applications and simulations. The software incorporates APIs, scene graph management, view culling, and collision detection, and is compatible with Visual Basic™ and Visual C++™. **Circle No. 717**

Servo Sizing Software

Servo Mechanical Analysis software from Industrial Indexing Systems, Victor, NY, allows users to model the mechanical elements of a system, choose various motion profile shapes, and analyze all aspects of motor/drive sizing. The software includes feed drive, ballscrew, and conveyor models, as well as a database of Delta Series™ motors and drivers with servo sizes from 30w to 14.3kW. The software predicts the regeneration capacity needed for the application, and the results can be stored in a file and/or printed in a summary. **Circle No. 718**

Development Software

Compaq Computer Corp., Nashua, NH, has released Version 6.5 of its Fortran 95 compiler for Windows. Compaq Visual Fortran for Windows 95, 98, 2000, and NT is a development system that includes the Fortran 95 compiler, a visual development environment from Microsoft, access to the Win32 Application Programmer Interfaces, and support for Fortran PowerStation and other Fortran language extensions. Designed for programming applications in scientific, engineering, and technical fields, Compaq Visual Fortran includes Visual C++ 6.0, and Microsoft's Studio toolset. **Circle No. 719**

New LITERATURE

Coupling Products

Colder Products, St. Paul, MN, has released a 60-page catalog featuring 100 new products, five new product lines, and over 1,000 standard products. Applications include general industrial bioprocessing, medical device, semiconductor, and food and beverage industries. Products include subminiature, general purpose, chemical handling, multiple line, dispensing, and specialty product couplings. **Circle No. 722**

Magnetic Shielding

A four-page brochure from Magnetic Shield Corp., Bensenville, IL, describes shielded cable, conduit, sleeving, and wire manufactured using CO-NETIC AA Alloy, designed to control low-frequency interference caused by magnetic fields. Featured are CO-NETIC AA Alloy braided sleeving, Spira-Shield flexible conduit, and Inter-8 weave cables. **Circle No. 723**

Industrial Hydraulics

Parker Hannifin Corp.'s Hydraulics Group, Cleveland, OH, has announced the availability of a CD-ROM catalog that includes over 3,000 pages of information on designing an industrial hydraulic system. Products include pumps, motors, cylinders, valves, electrohydraulics, accumulators, rotary actuators, and filtration products. **Circle No. 724**

Engineering Plastics

DSM Engineering Plastic Products, Reading, PA, has released a 47-page catalog of plastics for machining. Products include nylon for general-purpose structural components, acetyl products for parts in wet environments, Ertalyte® PET-P, PSU 1000 polysulfone, Radel R polyphenylsulfone, and Ultem polyetherimide. Each product listed includes applications for which it has been used. **Circle No. 725**

Communication/Data Acquisition

A 180-page catalog from Quatech, Akron, OH, features communication, data acquisition, and signal conditioning products. New products include the enhanced Freedom USB Series of USB-to-serial adapters, USB hubs, and USB PCMCIA card readers. Also included is the expanded QTM-8000 series of remote signal conditioning modules and wireless radio modem modules that extend a QTM network to over 1,000 meters. **Circle No. 726**

Editorial Index

Use the Web addresses listed below to obtain more information from the following companies featured editorially in this issue.

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COADE	www.coade.com	716	76
Colder Products	www.colder.com	722	77
Compaq Computer Corp.	www.compaq.com/fortran	719	76
Composite Optics	www.coi-world.com	740	22
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Rapid Product Development online

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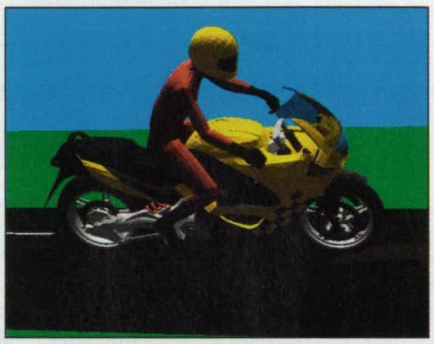
BMW Uses Computer Simulation to Ensure Motorcycle Stability



BMW engineers are achieving greater assurance of meeting stability requirements by using DADS mechanical system simulation software from LMS CADSI, Coralville, IA, to evaluate motorcycles through a wide range of potential dimensions. The computer simulation makes it easier to change the design parameters and configurations being evaluated. It also provides the opportunity to evaluate the performance of equipment under extreme conditions that could be dangerous, damaging, and expensive to perform on the test track.

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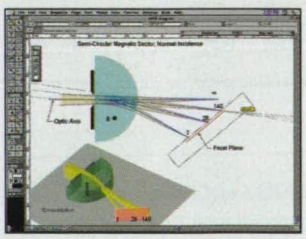
CAD Program Helps NASA Develop Miniature-Spectrometer Design

The basic design for an instrument to be used on a NASA mission was developed entirely in MiniCAD — a relatively inexpensive CAD system from Nemetschek North America, Columbia, MD. Instrument designers traditionally have used detailed mathematical calculations to design mass spectrometers. The difficulty with this approach is that the complexity of the equations involved makes it very easy to overlook alternate approaches that might reduce the size and magnetic moment of the instrument. Engineers at NASA Goddard Space Flight Center found that laying out the basic geometry in MiniCAD enabled them to easily conceptualize the design parameters and evaluate alternate approaches simply by manipulating the geometry.



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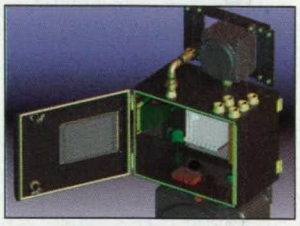

To repackage an existing instrument, reduce its size by one-quarter, and update its appearance, ABB Process Analytics turned to Solid Edge solid modeling software from Unigraphics Solutions, St. Louis, MO. This project was completed in three months — about one-quarter the time it would have taken using ABB's previous 2D CAD system. "One reason we were able to turn this project around so quickly was the software's sheet-metal modeling capability," said Todd Fenstermacher, an ABB mechanical engineer. "It did things like automatically calculate bend allowances and unfold the metal. The other big time-saver was how quickly we could make changes to the design."

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New Product Highlights

The Hyscan 45 from Hymarc 3D Vision Systems, Nepean, ON, Canada, is a high-performance 3D scanning laser digitizer that acquires XYZ data points from any object. It is designed to fit any coordinate measuring machine (CMM), computer numerically controlled (CNC) machine, or other translation device. Applications include reverse engineering, design, rapid prototyping, and inspection.

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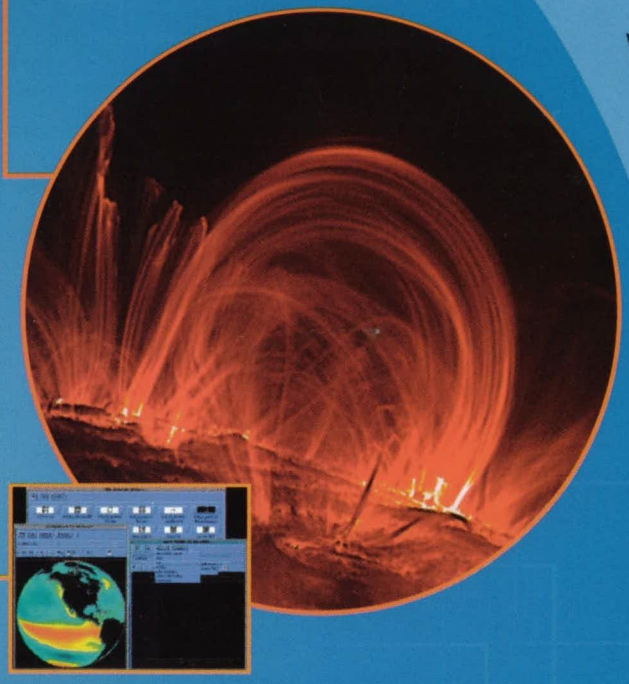

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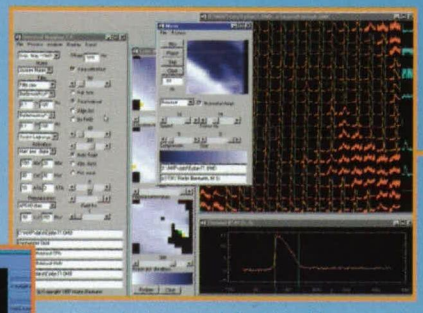

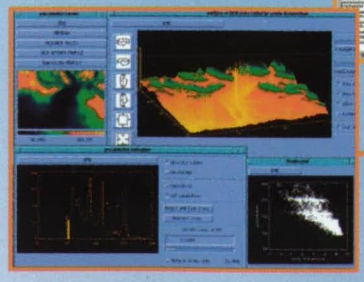

Circular image on left: Coronal loops over the Sun's eastern limb, courtesy of Dr. Robert Bentley, University College, London.

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